US012293745B2

(12) **United States Patent**
Senn

(10) **Patent No.: US 12,293,745 B2**
(45) **Date of Patent: May 6, 2025**

(54) **SYSTEM AND METHOD FOR CREATING A SENSORY EXPERIENCE BY MERGING BIOMETRIC DATA WITH USER-PROVIDED CONTENT**

(71) Applicant: **Paul Senn**, Swampscott, MA (US)

(72) Inventor: **Paul Senn**, Swampscott, MA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 459 days.

(21) Appl. No.: **17/808,936**

(22) Filed: **Jun. 24, 2022**

(65) **Prior Publication Data**

US 2022/0319477 A1 Oct. 6, 2022

Related U.S. Application Data

(63) Continuation-in-part of application No. 17/659,600, filed on Apr. 18, 2022, now abandoned, which is a
(Continued)

(51) **Int. Cl.**
G10H 1/00 (2006.01)
G06F 3/01 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC ***G10H 1/0008*** (2013.01); ***G06F 3/015*** (2013.01); ***G06F 3/017*** (2013.01); ***G10L 19/02*** (2013.01);
(Continued)

(58) **Field of Classification Search**
CPC G10H 1/0008; G10H 2240/056; G10H 2240/131; G06F 3/015; G06F 3/017; G10L 19/02; H04R 5/033; H04R 5/04
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

7,674,224 B2 3/2010 Hewett
10,264,990 B2 4/2019 Pasley et al.
(Continued)

OTHER PUBLICATIONS

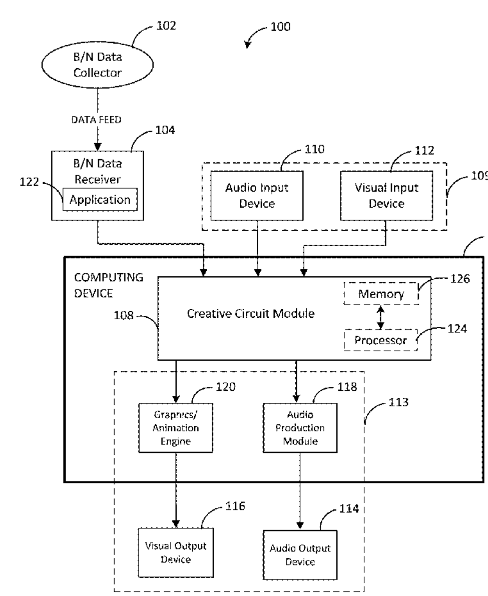
"Constant-Q Transform and Chroma," Web page https://musicinformationretrieval.com/chroma.html, 5 pages, Jul. 27, 2017, retrieved from Internet Archive Wayback Machine https://web.archive.org/web/20170727035250/https://musicinformationretrieval.com/chroma.html on Aug. 12, 2020.
(Continued)

Primary Examiner — Robert W Horn
(74) *Attorney, Agent, or Firm* — Neal, Gerber & Eisenberg LLP

(57) **ABSTRACT**

Systems and methods for generating sensory outputs (e.g., tactile, scent, and/or flavor) based on biometric/neurometric user data are provided. One exemplary method comprises receiving an incoming signal from a bio-generated data sensing device worn by a user; receiving an input signal representing sensory content experienced by the user in association with generation of the incoming signal; populating a common vocabulary with one or more values determined based on the input signal; determining a set of output values based on the incoming signal, the common vocabulary, which comprises a list of possible output values, and a parameter file, which comprises a set of instructions for applying the common vocabulary to the incoming signal to derive the set of output values; generating an output array comprising the set of output values; and providing the output array to an output delivery system configured to render the output array as a sensory output.

27 Claims, 31 Drawing Sheets



Related U.S. Application Data

continuation of application No. 16/872,940, filed on May 12, 2020, now Pat. No. 11,308,925.

(60) Provisional application No. 63/334,309, filed on Apr. 25, 2022, provisional application No. 62/885,307, filed on Aug. 11, 2019, provisional application No. 62/846,918, filed on May 13, 2019.

(51) **Int. Cl.**
G10L 19/02 (2013.01)
H04R 5/033 (2006.01)
H04R 5/04 (2006.01)

(52) **U.S. Cl.**
CPC ***H04R 5/033*** (2013.01); ***H04R 5/04*** (2013.01); *G10H 2240/056* (2013.01); *G10H 2240/131* (2013.01)

(56) **References Cited**

U.S. PATENT DOCUMENTS

10,321,842	B2 *	6/2019	Garten	A61B 5/486
10,369,323	B2	8/2019	Joseph	
10,534,900	B2 *	1/2020	Cheong	G06F 21/34
10,752,488	B2 *	8/2020	Bey	B67D 1/0035
10,832,643	B1	11/2020	Trim et al.	
11,140,486	B2 *	10/2021	Bae	H04M 1/72412
11,275,778	B2 *	3/2022	Marvaniya	A61B 5/6898
11,308,925	B2 *	4/2022	Senn	G06F 3/015
11,786,163	B2 *	10/2023	Garten	A61B 5/375 600/28
12,029,573	B2 *	7/2024	Garten	G16H 50/20
2007/0079691	A1	4/2007	Turner	
2015/0093729	A1	4/2015	Plans et al.	
2015/0297109	A1 *	10/2015	Garten	A61B 5/38 600/28
2016/0027423	A1	1/2016	Deuel et al.	
2016/0173982	A1	6/2016	Anderson	
2017/0172523	A1	6/2017	Temko et al.	
2017/0180911	A1	6/2017	Burton	
2018/0246570	A1	8/2018	Coleman et al.	
2019/0038237	A1	2/2019	Chafe et al.	
2019/0056707	A1 *	2/2019	Pollard	A61B 5/165
2019/0164156	A1	5/2019	Lindemann	
2019/0187802	A1 *	6/2019	Roh	G06F 3/0346
2019/0222918	A1	7/2019	Mackellar et al.	
2019/0288973	A1 *	9/2019	Liu	G06V 40/176
2019/0333487	A1	10/2019	Patitucci et al.	
2019/0387998	A1 *	12/2019	Garten	A61M 21/00
2020/0302825	A1 *	9/2020	Sachs	H04N 21/472
2020/0341548	A1 *	10/2020	Giordano	G06F 3/02
2020/0365125	A1	11/2020	Senn	
2021/0038857	A1	2/2021	Chattopadhyay et al.	
2021/0325834	A1	10/2021	Hiemstra et al.	
2022/0319477	A1 *	10/2022	Senn	G06F 3/016
2023/0368478	A1 *	11/2023	Huang	G06F 3/011

OTHER PUBLICATIONS

"Logic Pro X," Web page https://www.apple.com/logic-pro/, 17 pages, Apr. 30, 2019, retrieved from Internet Archive Wayback Machine, https://web.archive.org/web/20190430205121/https://www.apple.com/logic-pro/ on Aug. 12, 2020.

"Spire Health: Clinical-Grade Health Monitoring and Insights," Web page https://spirehealth.com/, 7 pages, Apr. 12, 2019, retrieved from Internet Archive Wayback Machine, <http://web.archive.org/web/20190412040851/https://spirehealth.com/> on Aug. 12, 2020.

"The Official MIDI Specification," Web page https://www.midi.org/specifications/, 3 pages, Apr. 30, 2019, retrieved from Internet Archive Wayback Machine https://web.archive.org/web/20190502030218/https://www.midi.org/specifications/ on Aug. 12, 2020.

Humanizing With Automation Envelopes, https://makingmusic.ableton.com/humanizing-with-automation-envelopes, Sep. 2015, 3 pp.

Introduction to OSC, <http://opensoundcontrol.org/introduction-osc> Jan. 2, 2008, 2 pp.

Mind Monitor, https://mind-monitor.com/, May 2010, 7 pp.

UnityOSC, Instruction Sheet, <http://thomasfredericks.github.io/UnityOSC/>, Aug. 5, 2017, 3 pp.

* cited by examiner

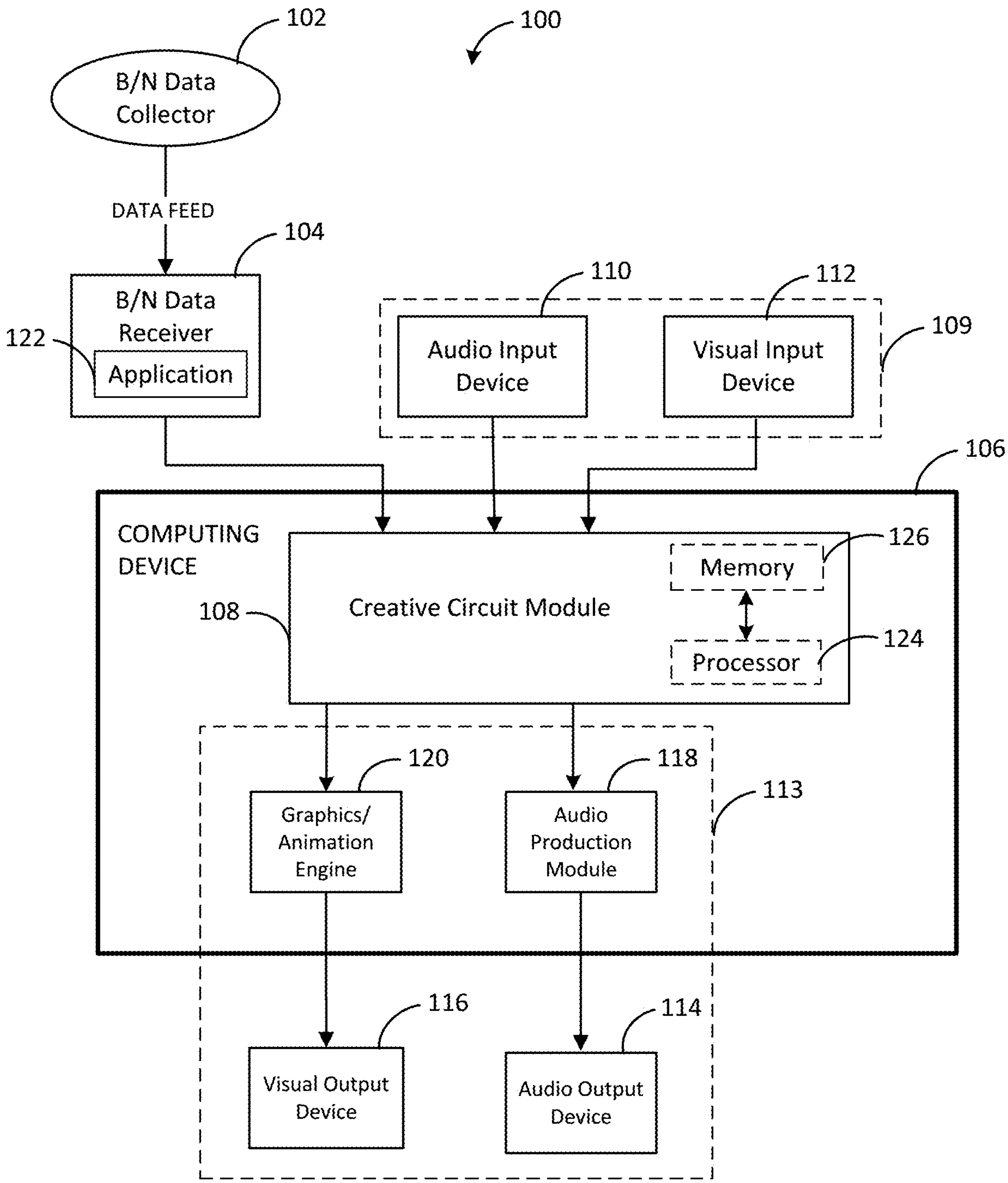
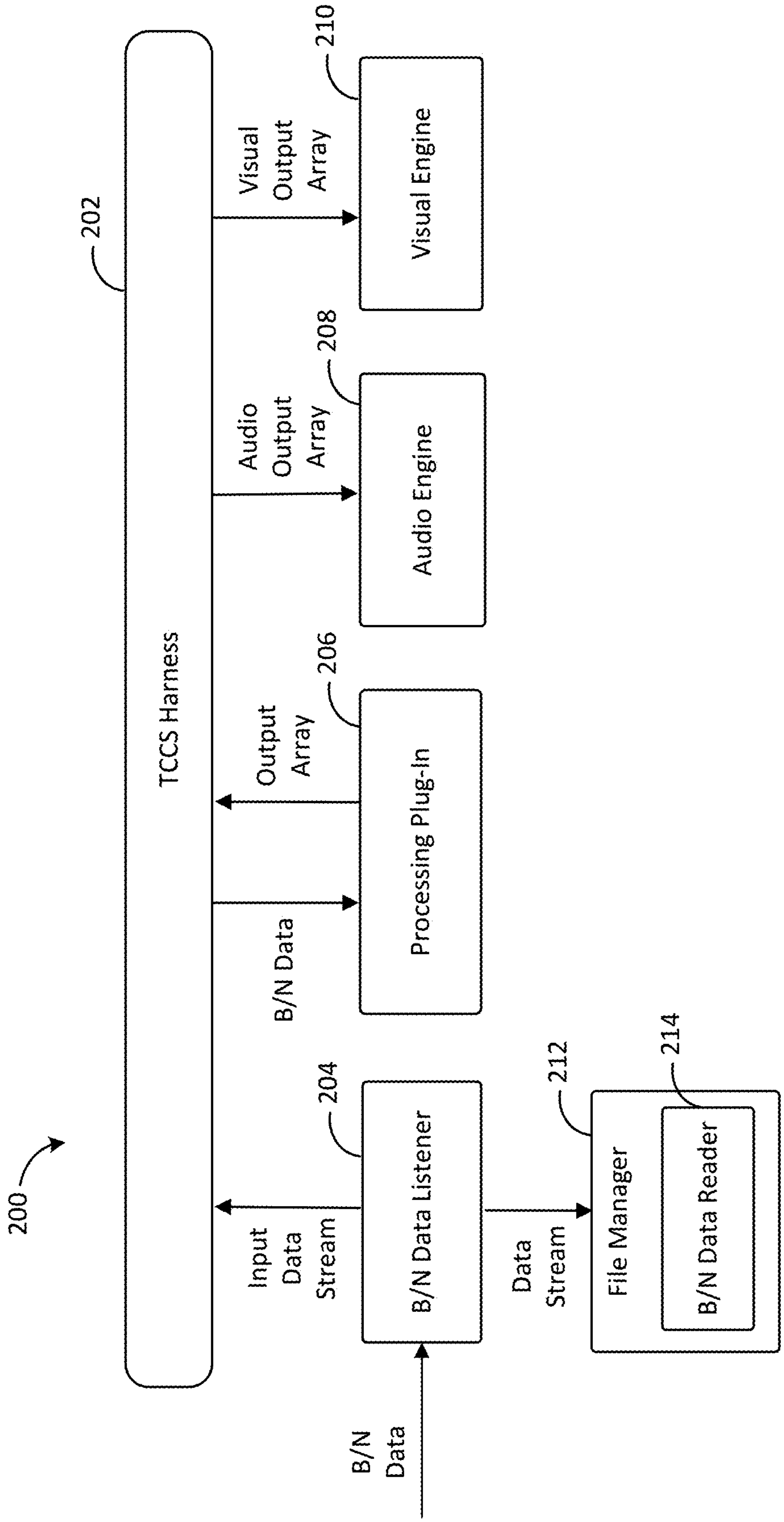

100
102
B/N Data Collector
DATA FEED
104
B/N Data Receiver
122
Application
110
Audio Input Device
112
Visual Input Device
109
106
COMPUTING DEVICE
126
Memory
108
Creative Circuit Module
124
Processor
120
118
113
Graphics/ Animation Engine
Audio Production Module
116
114
Visual Output Device
Audio Output Device

FIG. 1



200
202
TCCS Harness
204
B/N Data Listener
206
Processing Plug-In
208
Audio Engine
210
Visual Engine
212
File Manager
214
B/N Data Reader
B/N Data
Input Data Stream
Data Stream
B/N Data
Output Array
Audio Output Array
Visual Output Array

FIG. 2

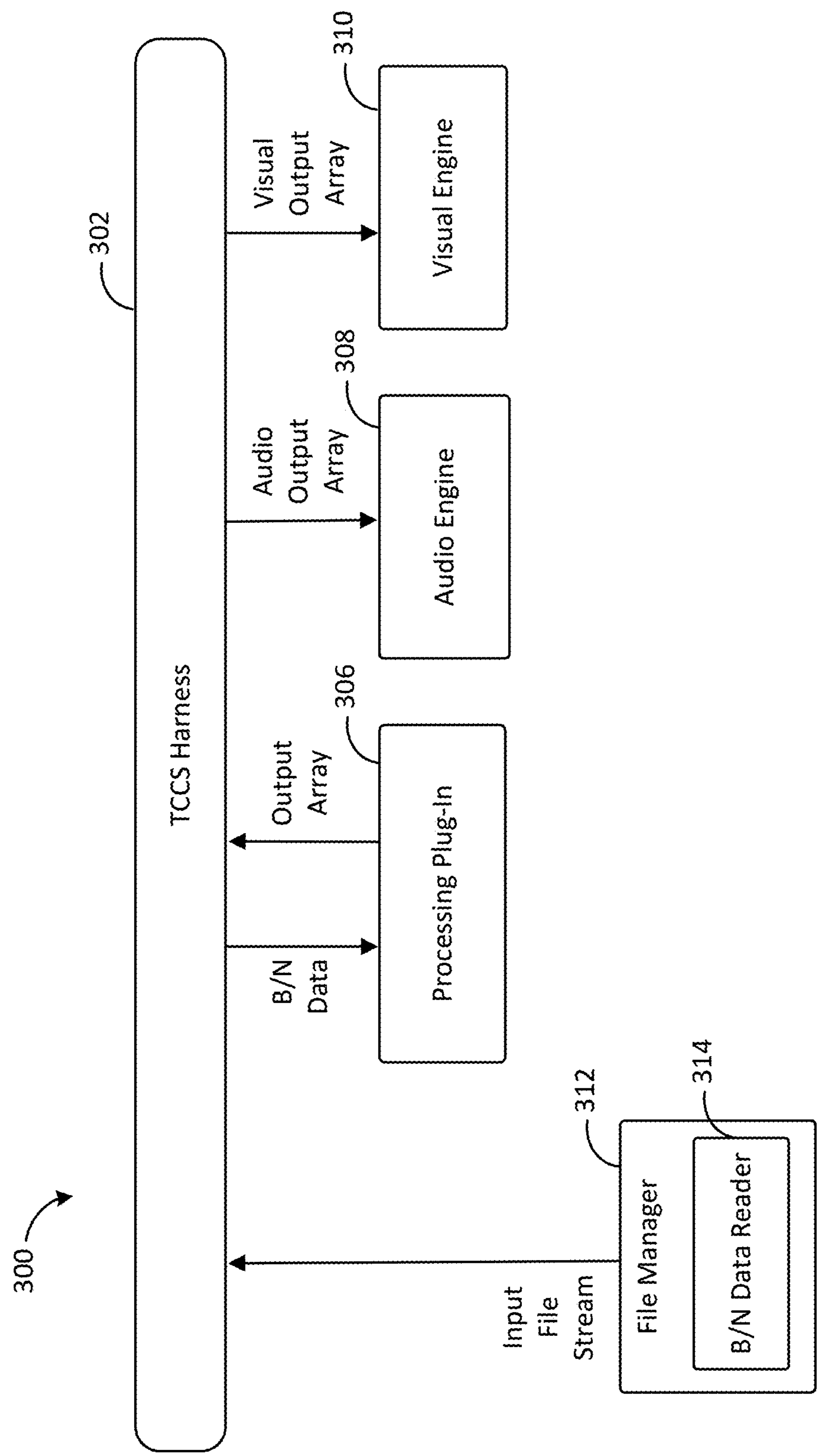

300
302
TCCS Harness
306
Processing Plug-In
B/N Data
Output Array
308
Audio Engine
Audio Output Array
310
Visual Engine
Visual Output Array
312
File Manager
314
B/N Data Reader
Input File Stream

FIG. 3

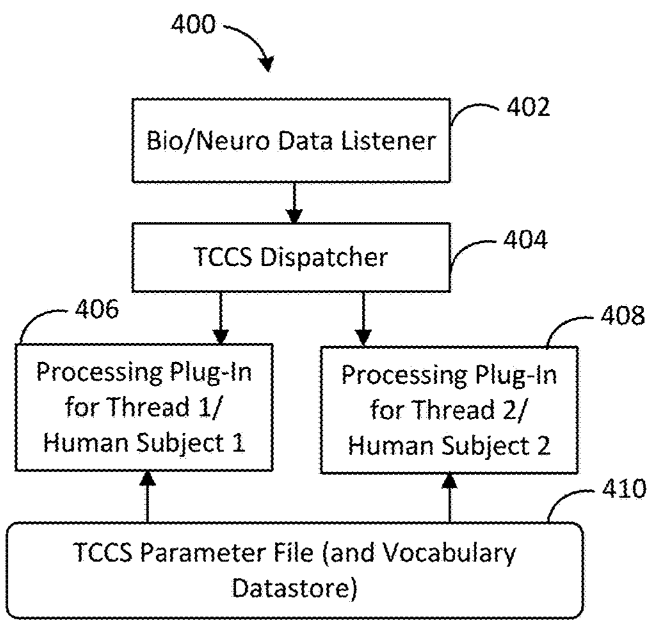

400
Bio/Neuro Data Listener
402
TCCS Dispatcher
404
406
Processing Plug-In for Thread 1/ Human Subject 1
408
Processing Plug-In for Thread 2/ Human Subject 2
410
TCCS Parameter File (and Vocabulary Datastore)

FIG. 4A

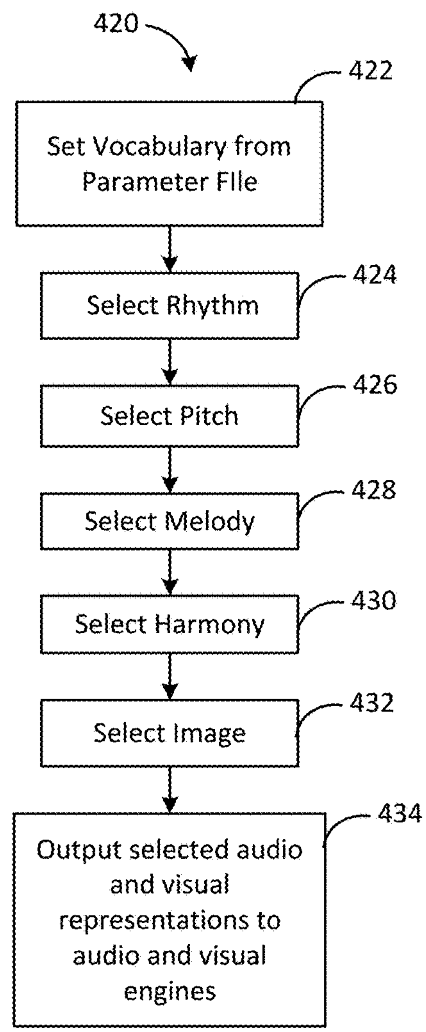

420
422
Set Vocabulary from Parameter FIle
424
Select Rhythm
426
Select Pitch
428
Select Melody
430
Select Harmony
432
Select Image
434
Output selected audio and visual representations to audio and visual engines

FIG. 4B

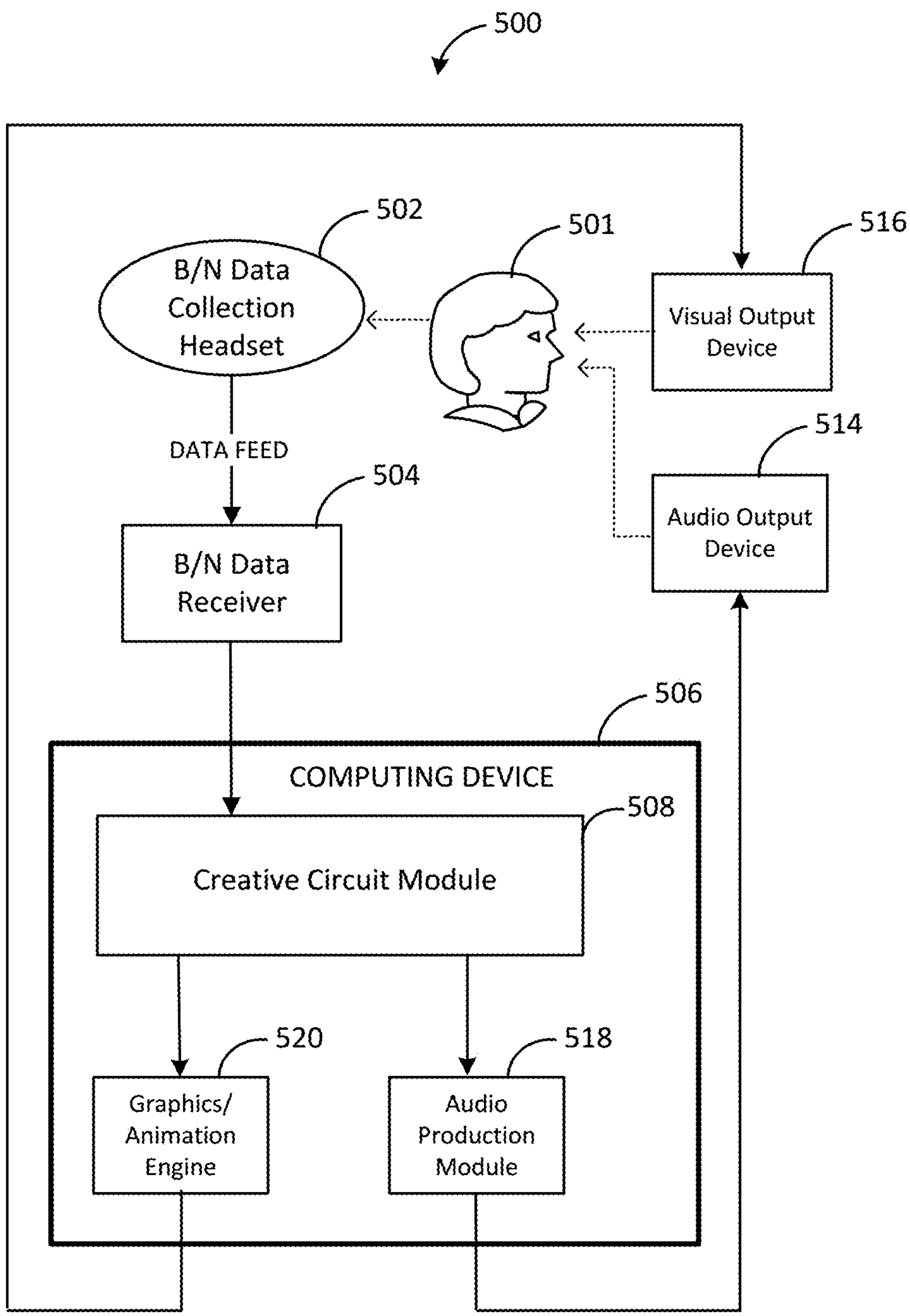
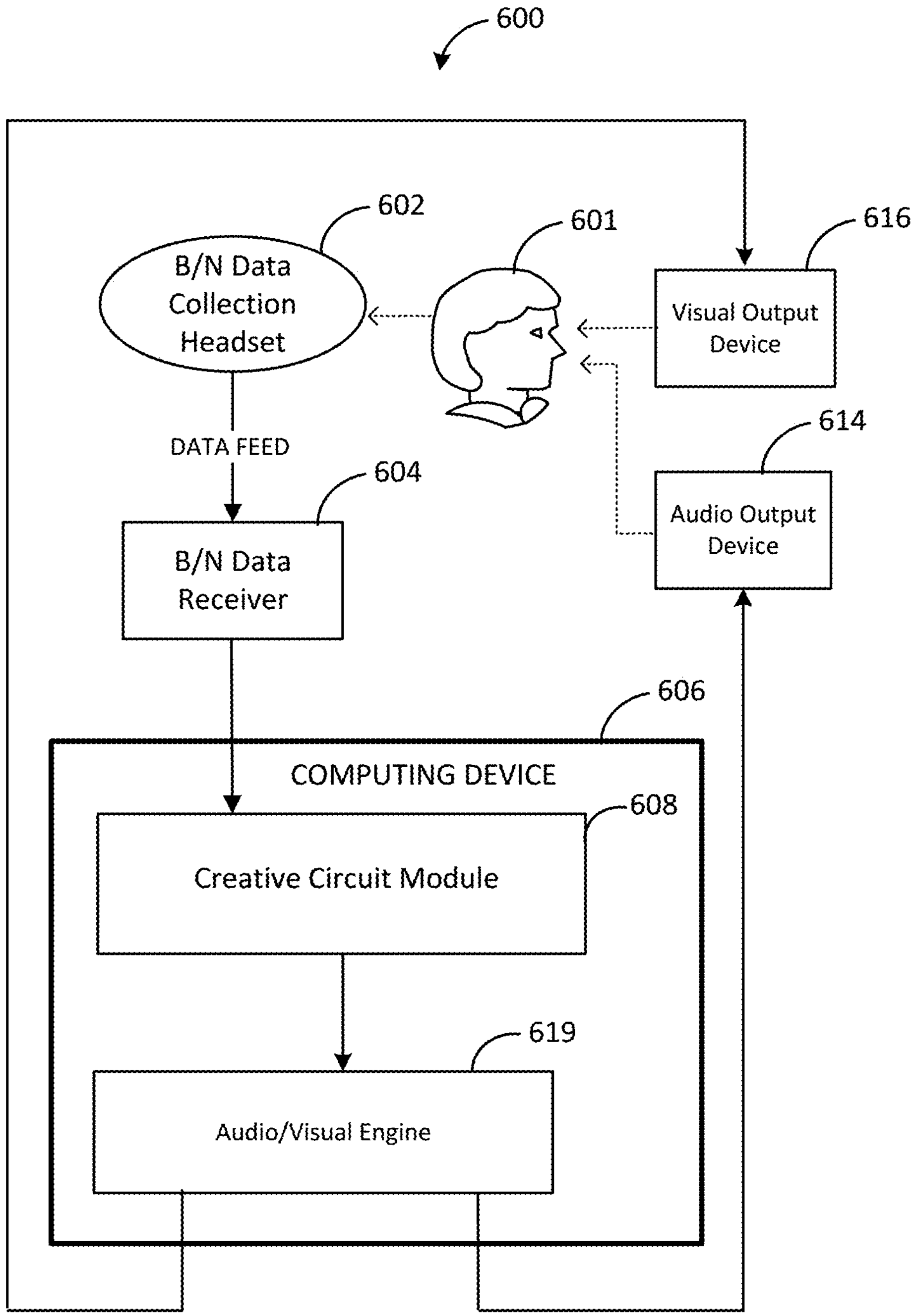
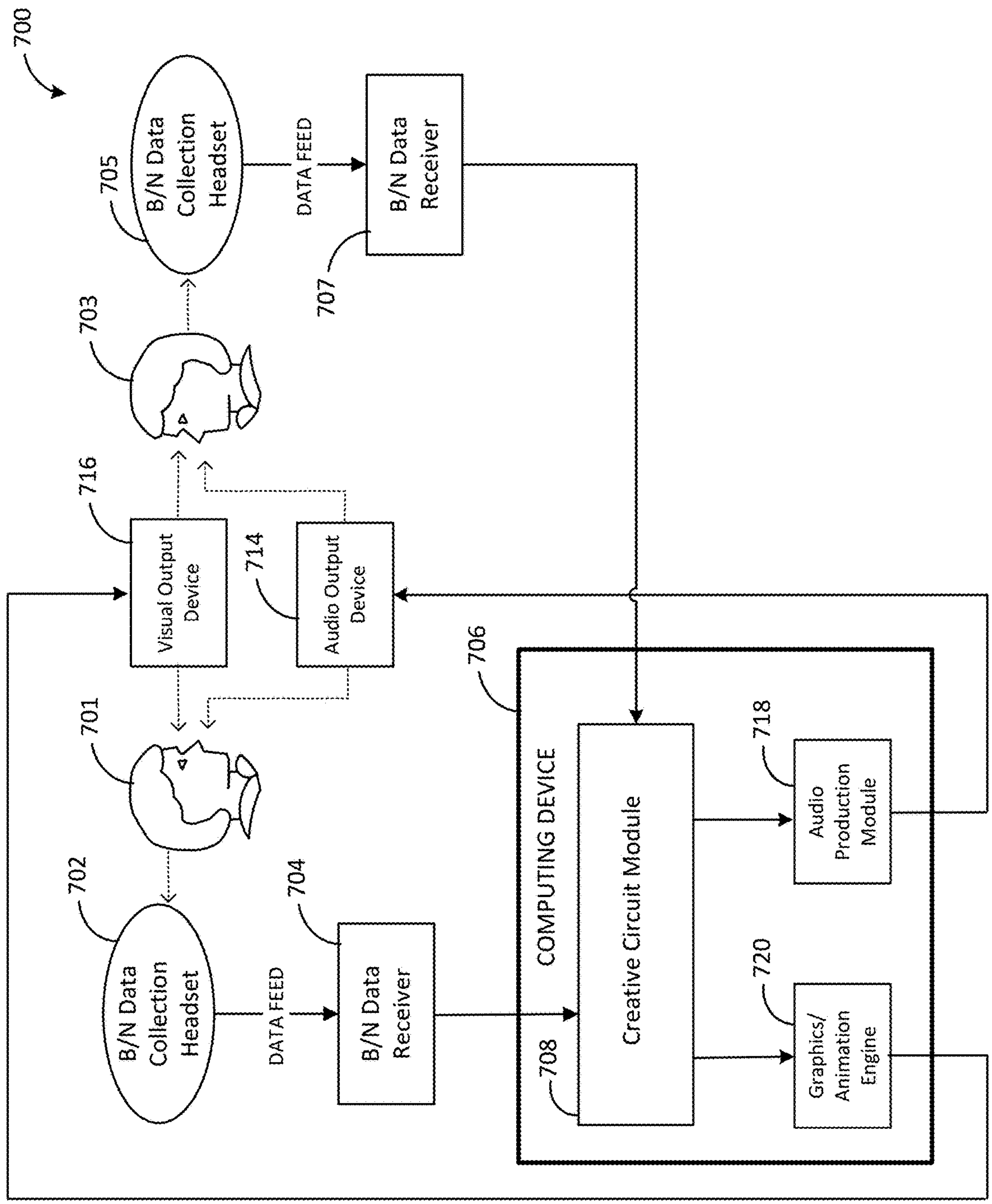

500
502
B/N Data Collection Headset
501
516
Visual Output Device
DATA FEED
514
504
Audio Output Device
B/N Data Receiver
506
COMPUTING DEVICE
508
Creative Circuit Module
520
518
Graphics/ Animation Engine
Audio Production Module

FIG. 5



600
602
B/N Data Collection Headset
601
616
Visual Output Device
DATA FEED
604
614
Audio Output Device
B/N Data Receiver
606
COMPUTING DEVICE
608
Creative Circuit Module
619
Audio/Visual Engine

FIG. 6



700
705
B/N Data Collection Headset
DATA FEED
B/N Data Receiver
707
703
716
Visual Output Device
714
Audio Output Device
701
706
COMPUTING DEVICE
Creative Circuit Module
708
718
Audio Production Module
720
Graphics/ Animation Engine
702
B/N Data Collection Headset
DATA FEED
704
B/N Data Receiver

FIG. 7

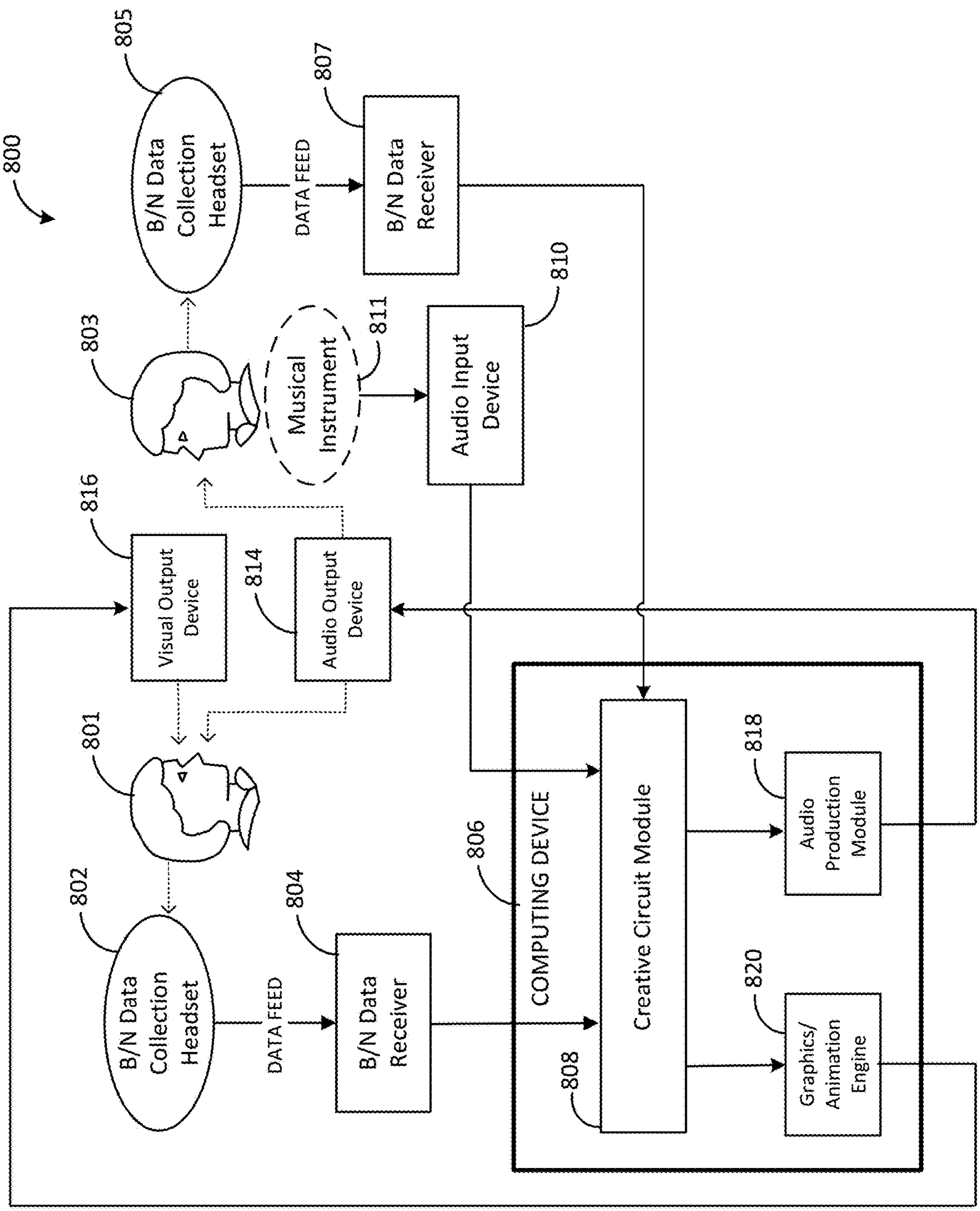

800
805
B/N Data Collection Headset
DATA FEED
807
B/N Data Receiver
803
811
Musical Instrument
810
Audio Input Device
816
Visual Output Device
814
Audio Output Device
801
802
B/N Data Collection Headset
DATA FEED
804
B/N Data Receiver
806
COMPUTING DEVICE
808
Creative Circuit Module
818
Audio Production Module
820
Graphics/ Animation Engine

FIG. 8

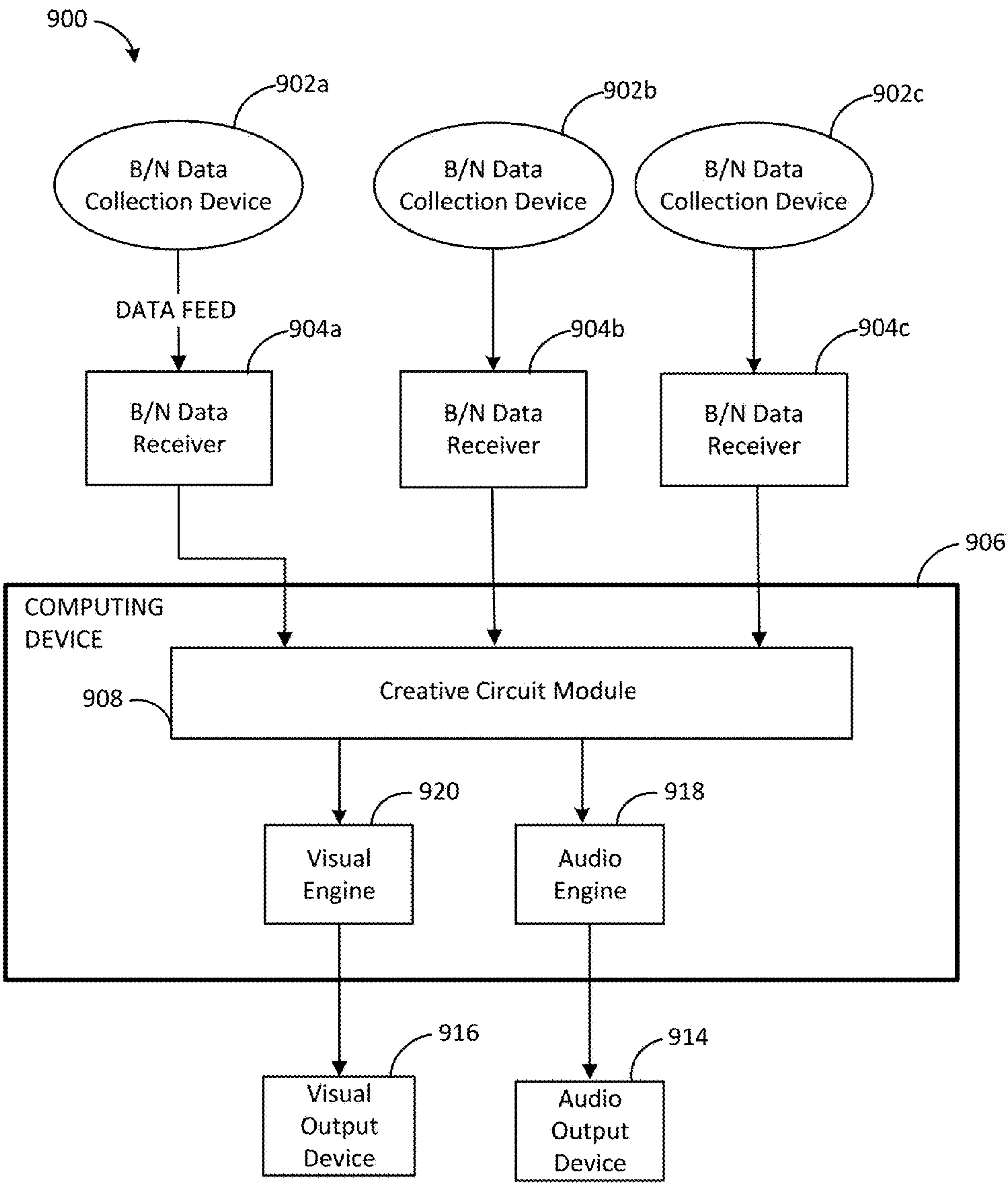

900
902a
B/N Data Collection Device
902b
B/N Data Collection Device
902c
B/N Data Collection Device
DATA FEED
904a
B/N Data Receiver
904b
B/N Data Receiver
904c
B/N Data Receiver
906
COMPUTING DEVICE
908
Creative Circuit Module
920
Visual Engine
918
Audio Engine
916
Visual Output Device
914
Audio Output Device

FIG. 9

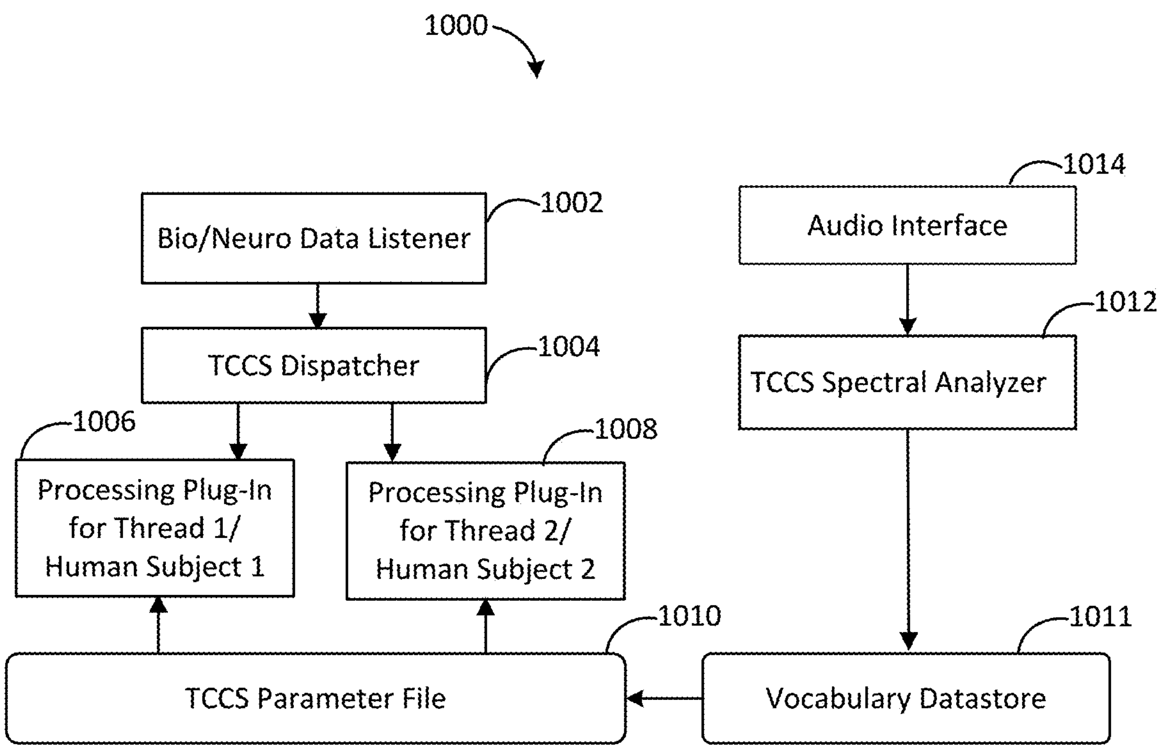

1000
Bio/Neuro Data Listener
1002
TCCS Dispatcher
1004
Processing Plug-In for Thread 1/ Human Subject 1
1006
Processing Plug-In for Thread 2/ Human Subject 2
1008
TCCS Parameter File
1010
Audio Interface
1014
TCCS Spectral Analyzer
1012
Vocabulary Datastore
1011

FIG. 10

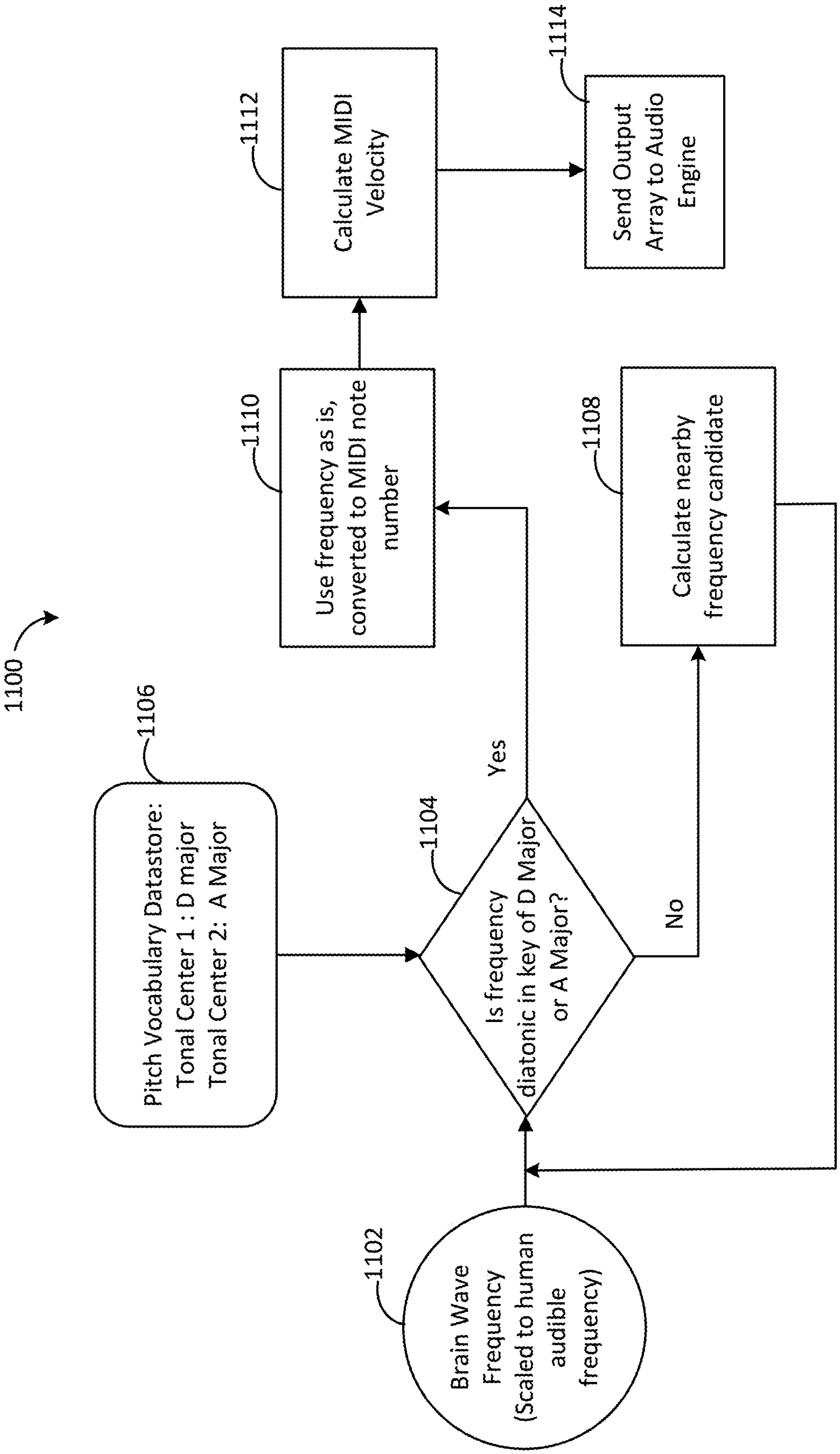

1100
Brain Wave Frequency (Scaled to human audible frequency)
1102
Pitch Vocabulary Datastore:
Tonal Center 1 : D major
Tonal Center 2: A Major
1106
Is frequency diatonic in key of D Major or A Major?
1104
Yes
No
Use frequency as is, converted to MIDI note number
1110
Calculate nearby frequency candidate
1108
Calculate MIDI Velocity
1112
Send Output Array to Audio Engine
1114

FIG. 11

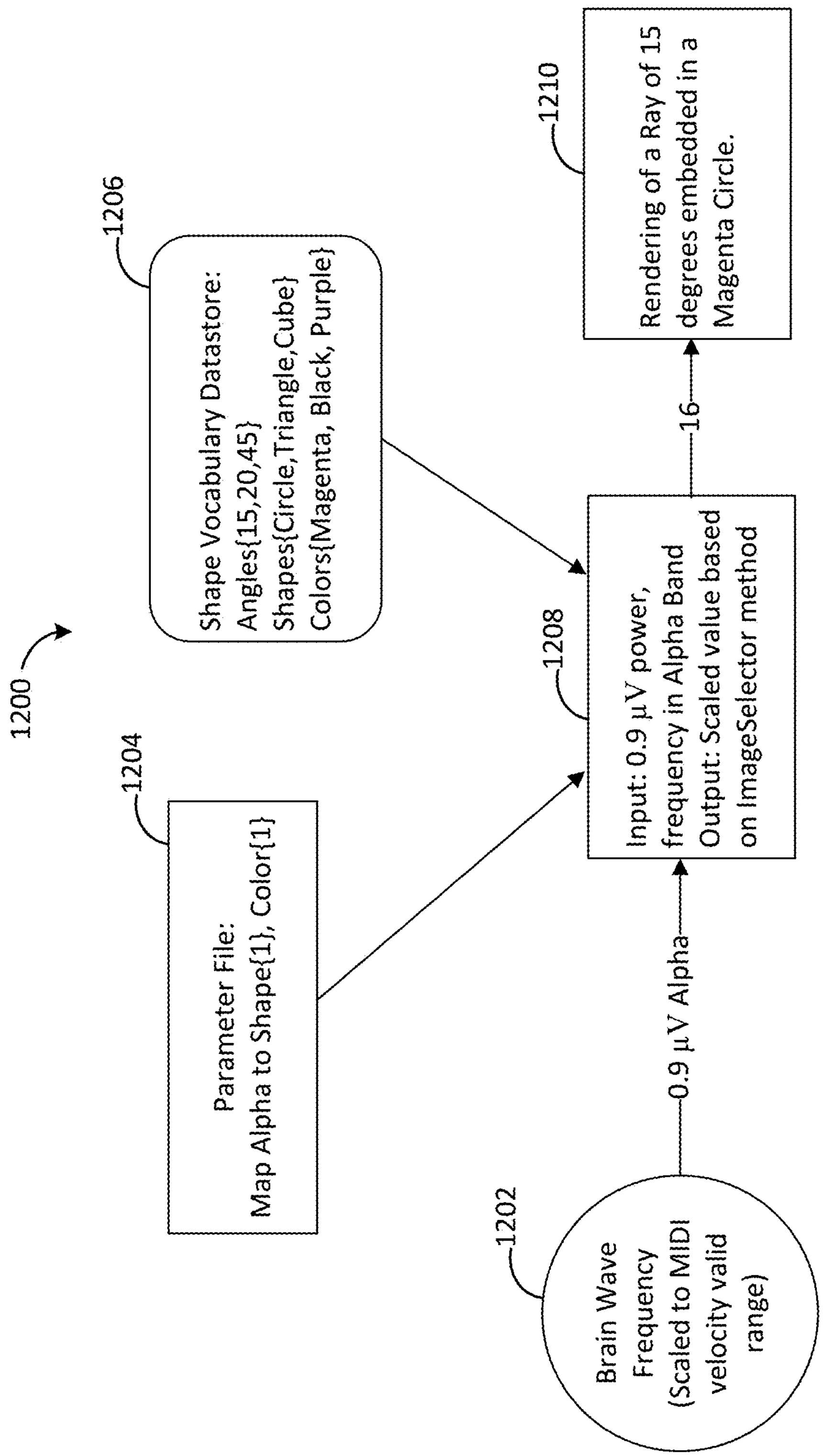

1200
1202
Brain Wave Frequency (Scaled to MIDI velocity valid range)
0.9 µV Alpha
1204
Parameter File:
Map Alpha to Shape{1}, Color{1}
1206
Shape Vocabulary Datastore:
Angles{15,20,45}
Shapes{Circle,Triangle,Cube}
Colors{Magenta, Black, Purple}
1208
Input: 0.9 µV power, frequency in Alpha Band
Output: Scaled value based on ImageSelector method
16
1210
Rendering of a Ray of 15 degrees embedded in a Magenta Circle.

FIG. 12

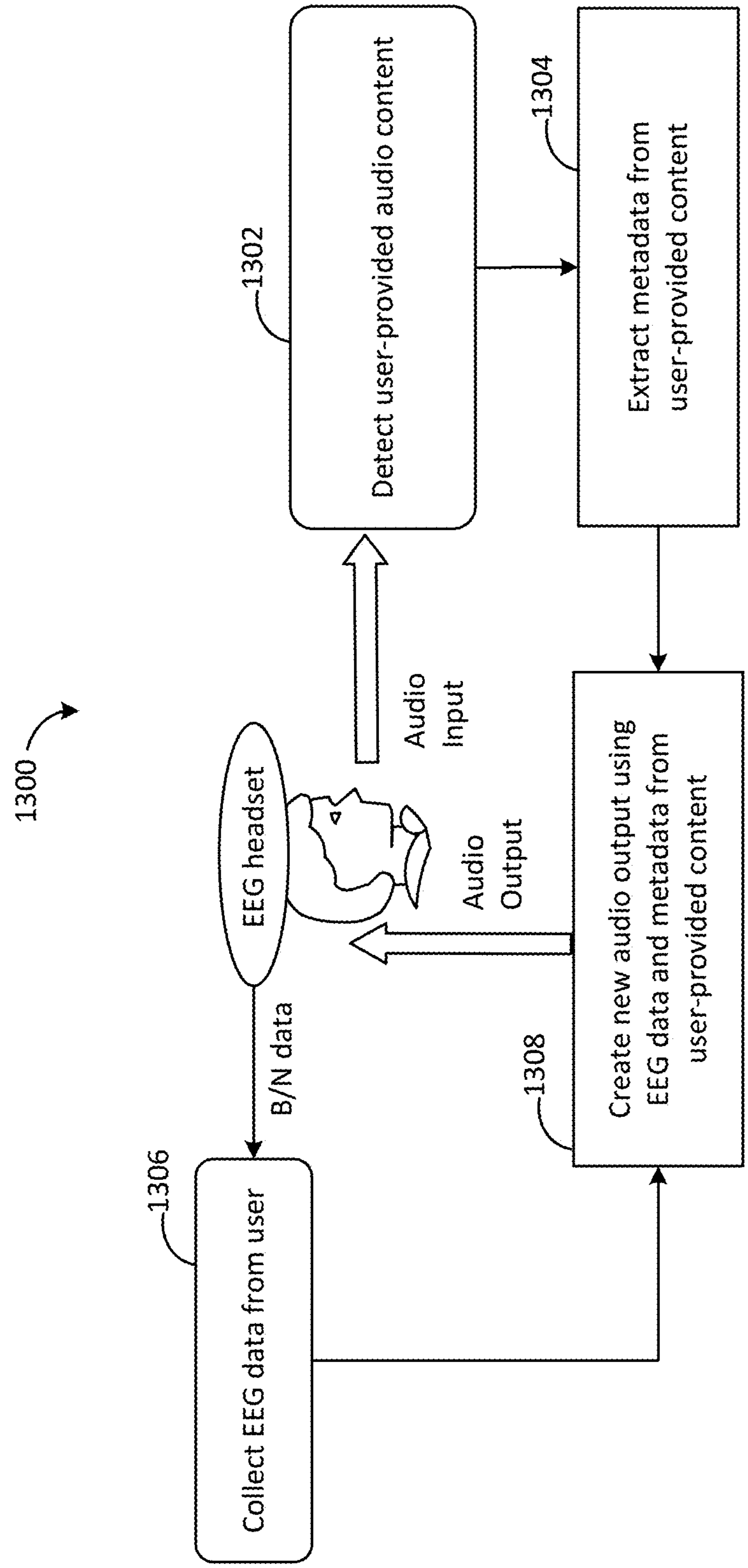

1300
1302
Detect user-provided audio content
1304
Extract metadata from user-provided content
Audio Input
EEG headset
Audio Output
B/N data
1306
Collect EEG data from user
1308
Create new audio output using EEG data and metadata from user-provided content

FIG. 13

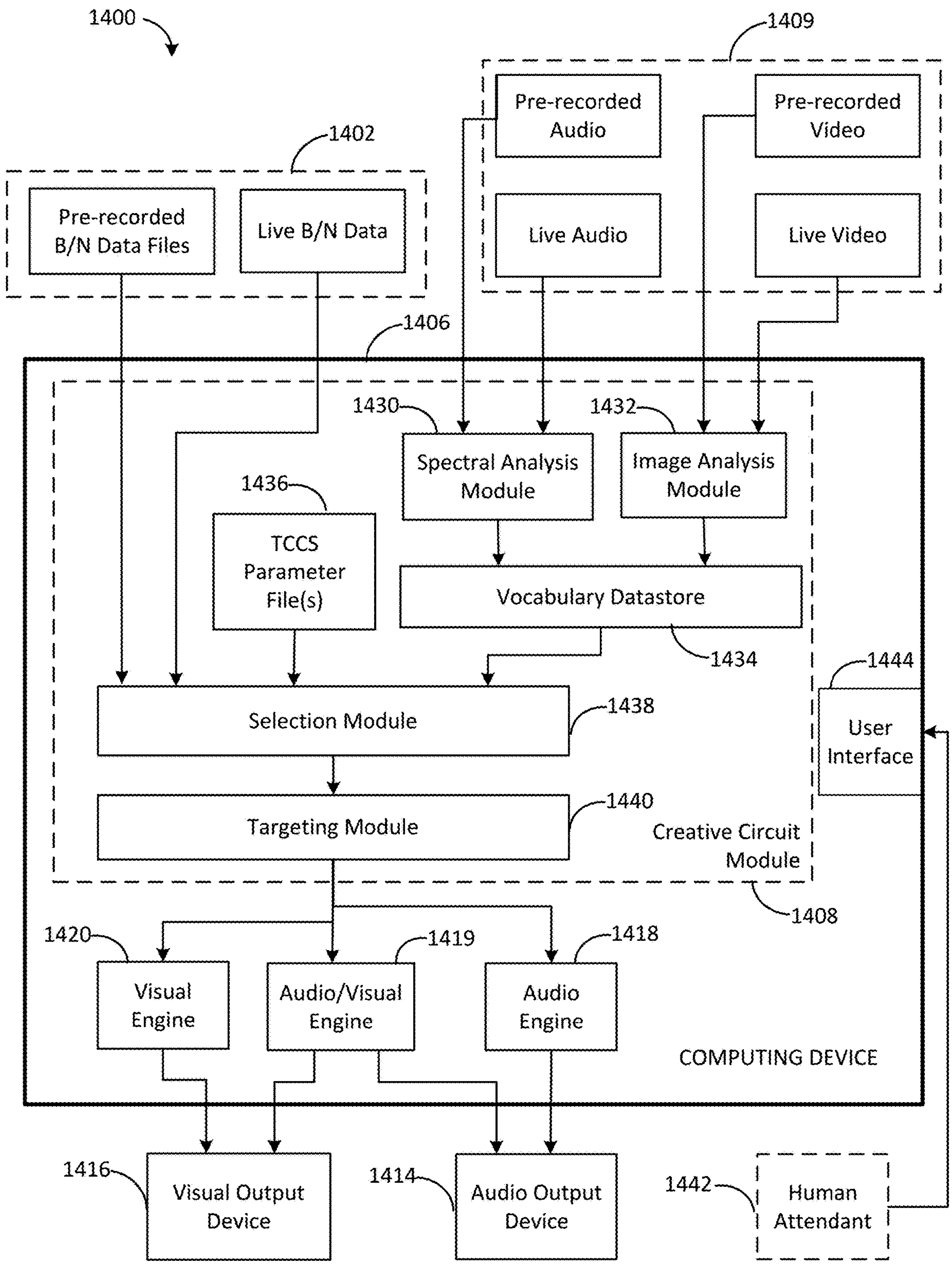

1400
1409
Pre-recorded Audio
Pre-recorded Video
1402
Pre-recorded B/N Data Files
Live B/N Data
Live Audio
Live Video
1406
1430
Spectral Analysis Module
1432
Image Analysis Module
1436
TCCS Parameter File(s)
Vocabulary Datastore
1434
1444
Selection Module
1438
User Interface
Targeting Module
1440
Creative Circuit Module
1408
1420
1419
1418
Visual Engine
Audio/Visual Engine
Audio Engine
COMPUTING DEVICE
1416
Visual Output Device
1414
Audio Output Device
1442
Human Attendant

FIG. 14

1500

Name of TCCS Parameter	Description	Use of Parameter in Audio Output	Use of Parameter in Video Output
TargetingPlugin	For each input data sample, call targeting plug-in and render appropriate output if threshold hit	Contains the logic that determines how audio stream will be affected if defined parameter ranges (or thresholds) are hit	Contains the logic that determines how video stream will be affected if defined parameter ranges (or thresholds) are hit
ProcessingPlugIn	This is code that makes use of defined parameters, and is called for each input data sample and produces output to be sent to Audio and/or Visual Processing Engine.	Contains the logic that determines how the defined parameters will affect the audio stream	Contains the logic that determines how the defined parameters will affect the video stream
Audio Engine	This system is responsible for audio production and will be where the instrumentation and other choices are made, for instance Logic Pro on a MAC with MIDI data coming in from Processing Plug-In and sent to MIDI channels.	The system will start the Audio Engine or expect it to be running, with open channels mapped to instruments, waiting for input from Processing Plug-In.	N/A
Visual Engine	This system is responsible for video and other visual production and will be where scripted animations, lines/shapes, rotations, scale, positions, colors or other visual structures and regions will be implemented.	N/A	The system will start the Visual Engine or expect it to be running, with threads of execution waiting for input from the Processing Plug-In. For instance, a version of Unity on the MAC could be running, with OSC data coming in from Processing Plug-In and processed using C# scripts attached to Unity Game Objects.

FIG. 15

1600

Name of TCCS Parameter	Description	Use of Parameters in Audio Output	Use of Parameters in Video Output	Example of Usage
Divisions	Tells how many notes or beats in each basic division	Allows for introduction of algorithms such that points of emphasis are put in at end of measures, or set based on measure boundary or modified based on measure boundary	Allows for introduction of algorithms such that animation, speed, line/shape, rotation, scale, position, color, boundaries can be set at end of measures, or modified based on measure boundary	Divisions = 2 DivisionType = Beats DivisionArray = {4,4} DivisionVocabularyTones = [{A, C#, E}, {E, G#, B}] DivisionVocabularySymbols = [{Circle, Square, Rectangle}, {Triangle, Cube, Line}] Could results in 2 divisions, each 4 beats long. In first division, tones used will be A, C#, and E, and shapes rendered will be Circle for A, Square for C#, and Rectangle for E.
NoteLength	Sets the base length of the quarter note	Allows for introduction of algorithms that use this length as a base and modifies it in formulas which include other elements below	Allows for introduction of algorithms that use this length as a base and modifies it in formulas which include other elements below	BaseNoteLength = .2 Could result in base length of quarter note being .2 seconds and base length of lines used in shape being .2 millimeter (mm).

Fbackground Key (primary pitch set)	Defines notes that will be considered primary	Allows for introduction of algorithms such that when a note is ambiguous, between two pitches in the well tempered system or other system of choice, the notes within the key are favored	Allows for introduction of algorithms such that visual maps are created matching the audio map represented by the well tempered or other system, and when a data value calculates to a point position that is ambiguous, between two regions, animations, animation speed, line/shape, rotation, scale, position, color or other visual boundaries, the point position that matches the	Key = [D, E, F#, G, A, B, C#]
				AlphaScaleFactor = 100
				def setPitchforAlpha (alphaVal)
				pitch = alphaVal*AlphaScaleFactor
				midival = getMidiNote(pitch)
				if (midival in Key)
				curMidiNote = midival
				else
				curMidiNote = nearestNote(Key, pitch, tonalCenter1)
				endif
				return curMidiNote
				end
				
				In this example, the biometric data showing current alpha power level is represented by variable alphaval, which is

FIG. 16A

1600

Name of TCCS Parameter	Description	Use of Parameters in Audio Output	Use of Parameters in Video Output	Example of Usage
			pre-established visual map is favored	scaled up by multiplying by 100 then sent to a function getMidiNote which returns the midi note represented by the scaled value. If the note is not in the key, a function nearestNote is called which returns nearest note in key. The resulting note can be mapped to a visual shape as shown in the Divisions row above.

TonalCenter1	Defines note that will be considered center (allows modes)	Allows for introduction of algorithms biased to produce this note more frequently than others	Allows for introduction of algorithms biased to produce animations, animation speed, line/shape, rotation, scale, position, color or other visual characteristic more frequently than others	Key = [D, E, F#, G, A, B, C#]
				TonalCenter1 = 'D'
				Example function in pseudo-code:
				def nearestNote(key, pitch, tonalCenter)
				midival = getMidiNote(pitch)
				if (midival in key)
				curMidiNote = midival
				else
				tmp1 = getMidiNote(key, pitch+1)
				tmp2 = getMidiNote(key, pitch-1)
				# favor tonal center by order of
				# conditional checks
				if (tmp1 in Key and
				tmp1 == tonalCenter)
				return tmp1
				elseif (tmp2 in Key and
				tmp2 == tonalCenter)
				return tmp2
				elseif (tmp1 in Key)
				return tmp1
				elseif (tmp2 in Key)
				return tmp2
				else
				return curMidiNote
				end
				end

FIG. 16B

1600

Name of TCCS Parameter	Description	Use of Parameters in Audio Output	Use of Parameters in Video Output	Example of Usage
				The resulting note can be mapped to a visual shape as shown in the Divisions row above.

Randomness Factor (can be an attribute of every parameter above)	Allows for introduction of randomness in application of other parameters	Could be applied to any parameter to introduce an element of randomness through application of a different algorithm or algorithms, the frequency of which is determined by randomness factor	Could be applied to any parameter to introduce an element of randomness through application of a different algorithm or algorithms, the frequency of which is determined by randomness factor	Random[NoteLength] = .50
				def varyNoteLength(noteLength)
				tmp = RandomRange(0.0, 1.0)
				if (tmp < Random[NoteLength])
				return noteLength -1
				else
				return noteLength
				endif
				end
				# function will shorten note length by 1 50% of the time

FIG. 16C

1700

Creative Circuit	Description	Example Usage	Comment
Intrapersonal Spoken/sung/chanted word ←→ Mind	Output Sensory experience is blend of EEG and auditory characteristics of subject's voice	Guided meditation or hypnosis	Individual can interact with their own brain waves, either all or with selected EEG bands (alpha, theta, etc)
Intrapersonal Musical Instrument ←→ Mind	Output Sensory experience is blend of EEG and auditory characteristics of instrument	Creative improvisation practice or performance	Individual can interact with their own brain waves, either all or with selected EEG bands
Intrapersonal Mind ←→ Mind	Different EEG bands can be set to different algorithmic treatment and channels, Sensory experience is blend of output of individual bands	Setup system so Alpha power level is flute, interacting with violin driven by Beta power	Individual can see and hear the interplay between different EEG wave lengths as a musical/visual experience.
Interpersonal Spoken/sung/chanted word ←→ Mind	Output Sensory Experience is blend of EEG outputs from 1, 2 or more individuals and auditory characteristics of 1, 2 or more subjects' voices	1 person speaks, multiple people wear EEG headsets and listen, or a two person circuit, with both alternately speaking and listening and both wearing headsets	A creative circuit between 1 or more individuals and their audience, or between 2 people interacting, or between 2 groups interacting
Interpersonal Musical Instrument ←→ Mind	Output Sensory Experience is blend of EEG outputs from 1, 2 or more individuals and auditory characteristics of 1, 2 or more instruments	1 musician wearing headset, multiple people wearing headset listening, or multiple musicians playing, wearing headsets	Creative Circuit can be between musicians, between musicians and audience, between audience members, or all of the above
Interpersonal Mind ←→ Mind	The Output Sensory Experience produced by 1 person or group's brain waves is recorded and used as base for musical vocabulary of another person or group, so	Could be simply 2 people face to face, wearing headsets	Creative Circuit for "MindMerge" experience between individuals or groups

FIG. 17A

1700

Creative Circuit	Description	Example Usage	Comment
	this output is itself the "User provided content" rather than the spoken word or instrument		
Playback mode EEG file input ←→ EEG file input	By looping different files of different lengths with different mappings, continuously varying audio/visual experience can be generated	Background music or texture for massage or relaxation	Creative circuit renewing the past brings it to life and can have overlaid significance for listeners if the files represent content from a significant past event or individual or group.
Interpersonal or intrapersonal Hybrid Playback/Real-Time mode EEG file input ←→ Mind	Output Sensory Experience is blend of EEG outputs from 1, 2 or more individuals and EEG output from previously recorded file(s)	A file may hold EEG output from a previous individual or group that a person wants to re-experience and interact with.	Creative circuit between the present and the past can have therapeutic or inspirational value.
Interpersonal or intrapersonal Hybrid Recorded Audio ←→ Mind	Output Sensory Experience is blend of EEG outputs from 1, 2 or more individuals audio output from arbitrary audio recording	A favorite song can create an audio texture that the system analyzes and uses as base musical vocabulary for EEG, i.e. music algorithm	Creative circuit between a user's mind and their favorite song.

FIG. 17B

1800

```
import keys
cycleLength=128
cycleIterations=600
maxonly=False
enableRecord=False
playInvitation=False
playRecordingPrompts=False
usestarters=False
playstartertones=False
musicalinput=False
recordOnlyOnce=True
pauseLength=0
samplingPace=0
segmentLengths=[32,64,96,128]
primaryNotes=["C","A", "F", "G"]
secondaryNotes=["G","E-","C","B-"]
drumPreferredNotes=["C", "C#", "D", "D#"]
starterScaleNotes=["C#5", "F#4", "C#6","B5", "E4",
"G6","A#5", "C6", "D6", "G4", "A2", "A4", "G#5"]
starterPreferredNotes=["E", "F#", "G", "A"]
starterTertiaryNotes=["C#", "D", "E", "F#"]
preferredNotesArray=[["A", "E", "F",  "C"],["C", "D", "F",
"A","G"],["E", "B", "D","C","G"],["A", "D", "F",
"E","G"],["C", "A", "B",  "E", "B","G"]]
#samplingPaces=[30,30,80,20]
samplingPaces=[1,1,1,1]
centralNote="D"
skipNote="D-"
midiInCount=6
midiIn=[0,0,0,0,0,0]
volumeControl="raw4"
dissonanceControl="OFF"
rhythmicControl="beta,gamma"
pitchControl="alpha,theta,raw2,raw3,raw4"
tempoControl="gamma"
intervalControl="delta"
harmonicControl="raw1"
```

FIG. 18

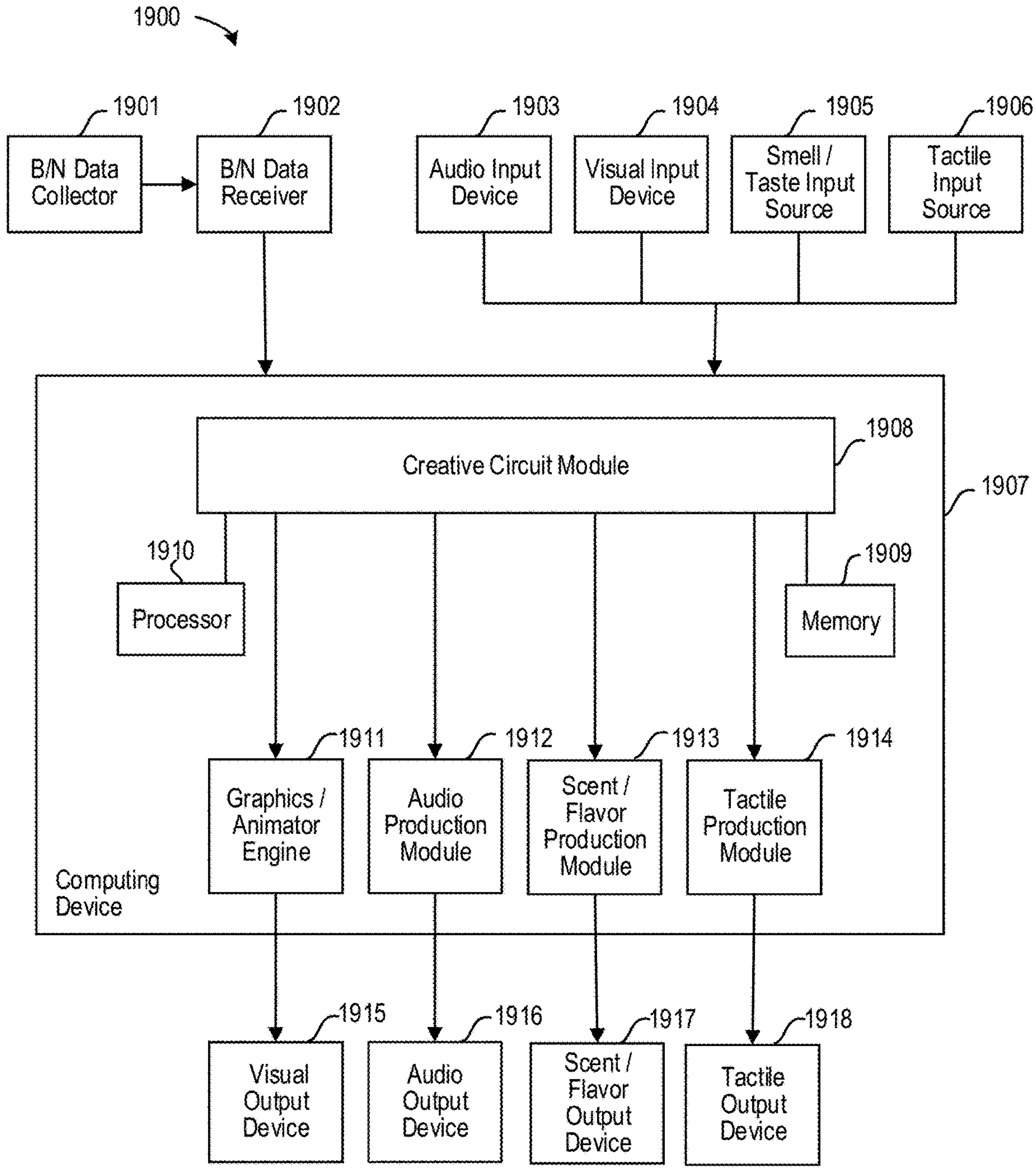

1900
1901
B/N Data Collector
1902
B/N Data Receiver
1903
Audio Input Device
1904
Visual Input Device
1905
Smell / Taste Input Source
1906
Tactile Input Source
1907
1908
Creative Circuit Module
1910
Processor
1909
Memory
1911
Graphics / Animator Engine
1912
Audio Production Module
1913
Scent / Flavor Production Module
1914
Tactile Production Module
Computing Device
1915
Visual Output Device
1916
Audio Output Device
1917
Scent / Flavor Output Device
1918
Tactile Output Device

Fig. 19

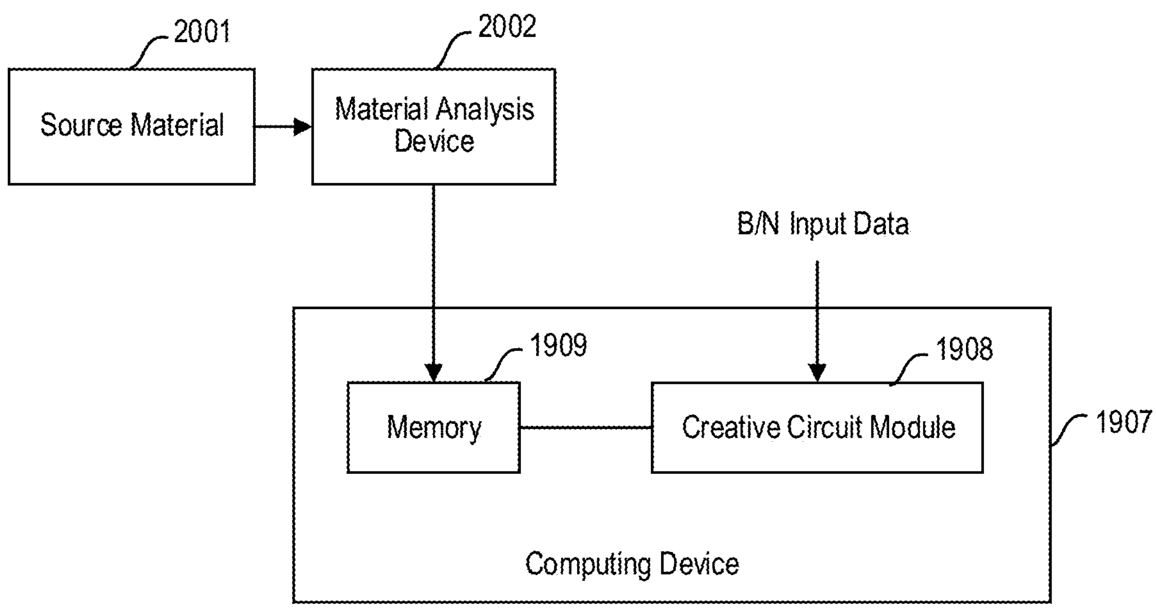

2001
Source Material
2002
Material Analysis Device
B/N Input Data
1909
Memory
1908
Creative Circuit Module
1907
Computing Device

Fig. 20

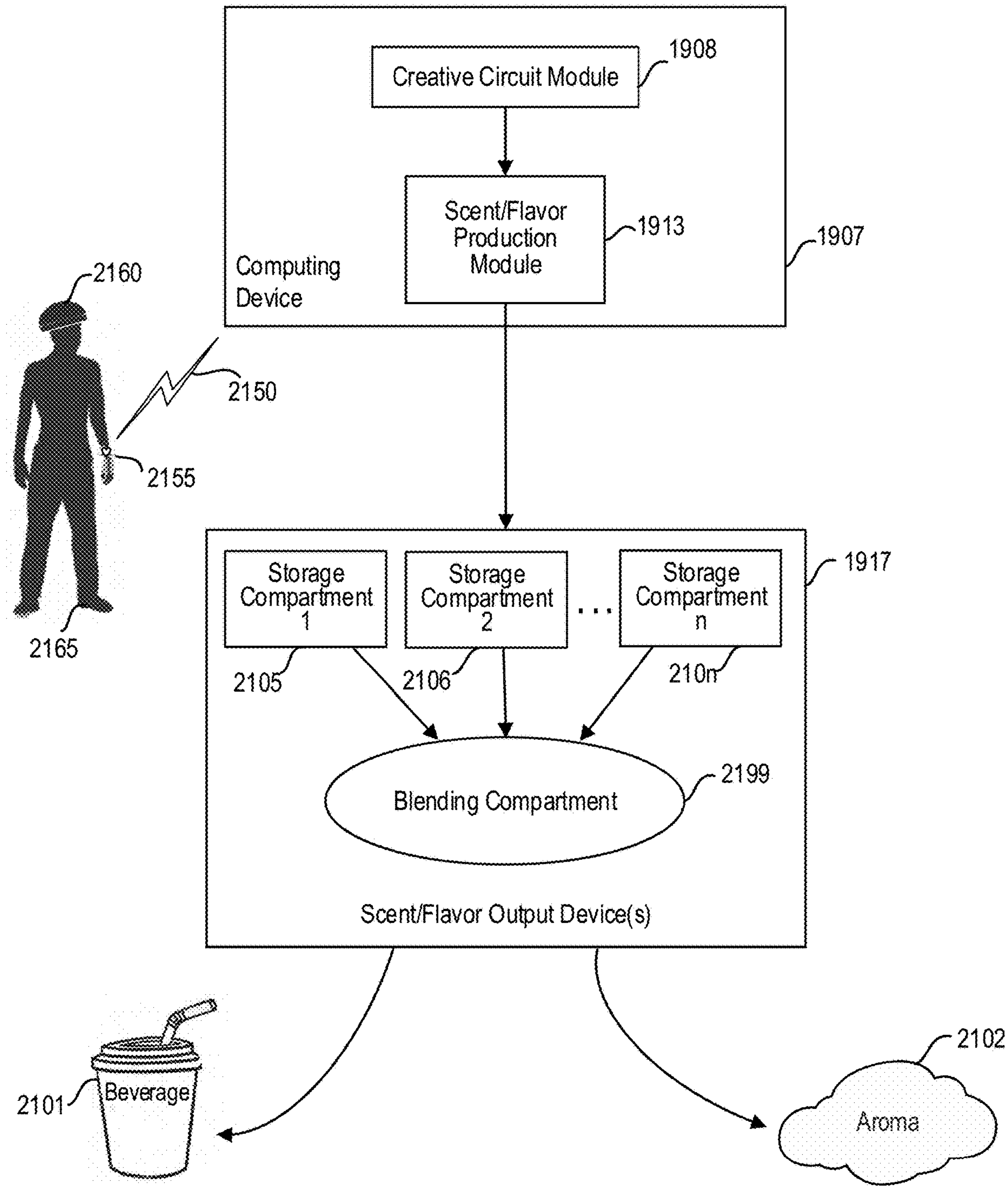

Creative Circuit Module
1908
Scent/Flavor Production Module
1913
Computing Device
1907
2160
2150
2155
2165
Storage Compartment 1
Storage Compartment 2
Storage Compartment n
. . .
1917
2105
2106
210n
Blending Compartment
2199
Scent/Flavor Output Device(s)
2101
Beverage
2102
Aroma

Fig. 21

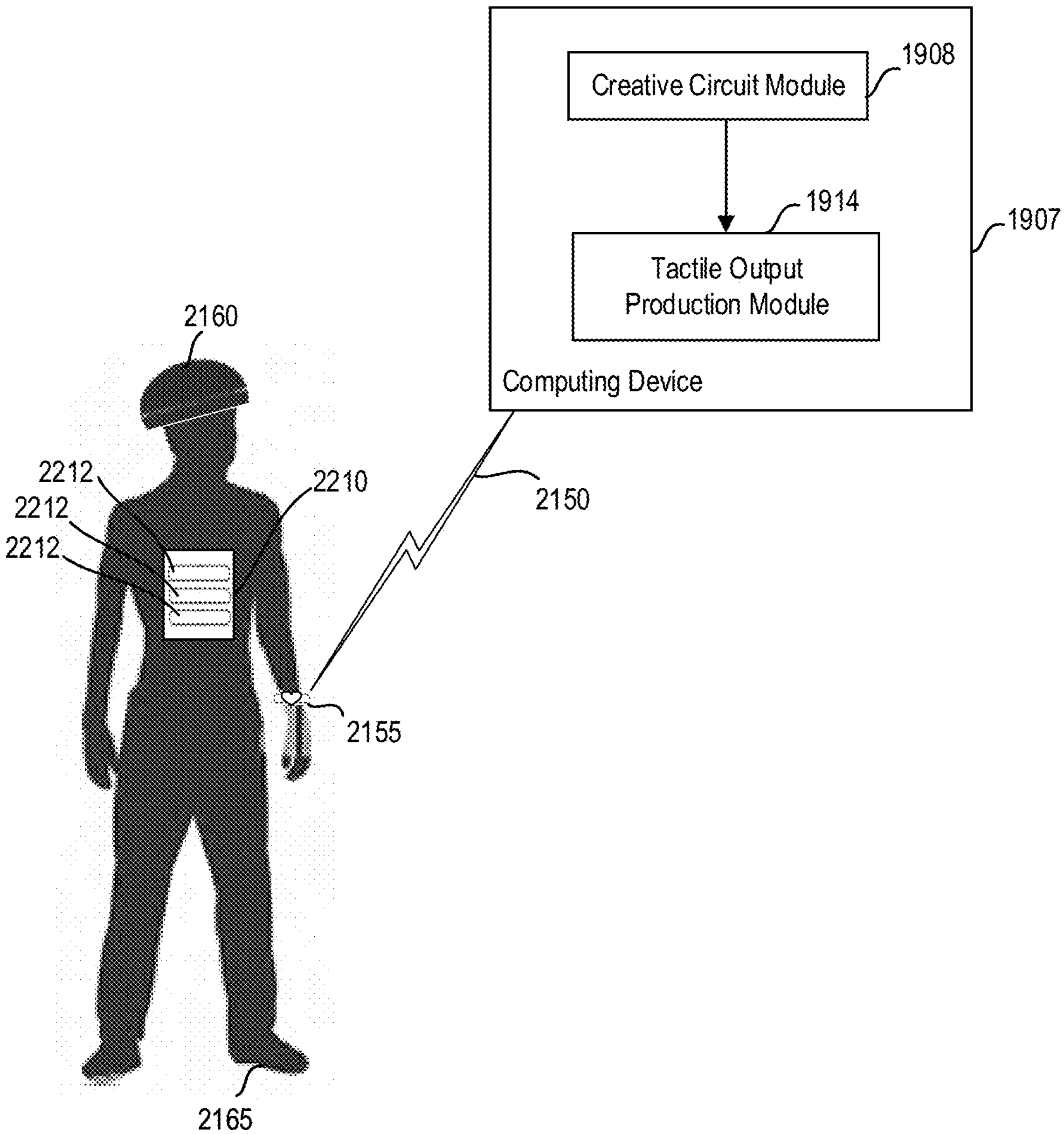

Creative Circuit Module
1908
1914
1907
Tactile Output Production Module
Computing Device
2160
2212
2212
2212
2210
2150
2155
2165

Fig. 22

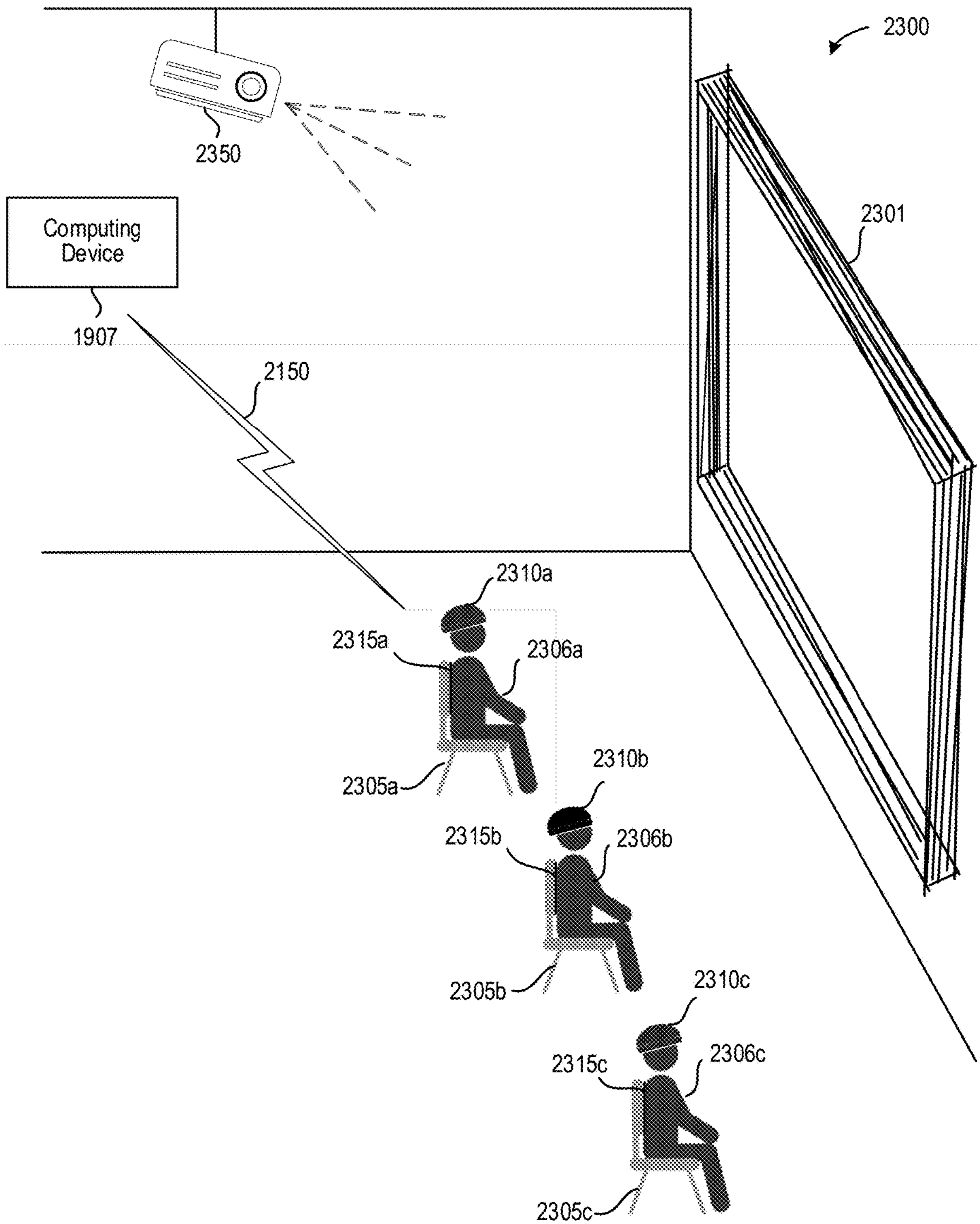

2300
2350
2301
Computing Device
1907
2150
2310a
2315a
2306a
2305a
2310b
2315b
2306b
2305b
2310c
2315c
2306c
2305c

Fig. 23

2400

Name of TCCS Parameter	Description	Use of Parameter in Tactile Output	Use of Parameter in Flavor/Scent Output
Targeting Plugin	For each input data sample, call targeting plug-in and render appropriate output if threshold hit.	Contains the logic that determines how tactile output will be affected if defined parameter ranges (or thresholds) are hit	Contains the logic that determines how flavor/scent output will be affected if defined parameter ranges (or thresholds) are hit
Processing Plugin	This is code that makes use of defined parameters, and is called for each input data sample and produces output to be sent to appropriate Processing Engine	Contains the logic that determines how defined parameters will affect the audio stream	Contains the logic that determines how defined parameters will affect the audio stream
Tactile Engine	This system is responsible for Tactile production, for instance a Smart back massage device with the capability to deliver touch at a given pressure and pulse speed	The system will connect to the Tactile Engine, for instance by establishing a network connection to a Smart back massage device capable of receiving control commands	N/A
Flavor/Scent Engine	This system is responsible for Flavor or Scent production, for instance a Smart Drink dispensing device with the capability to deliver a beverage containing different proportions of pre-loaded liquids	N/A	The system will connect to the Flavor/Scent Engine, for instance by establishing a network connection to a Smart drink dispensing device capable of receiving control commands

Fig. 24

2500

Name of TCCS Parameter	Description	Use of Parameters in Tactile Output	Example of Usage
PressureLevel	Sets the base range for applied pressure (could be a number or word signifying a range of numbers)	Allows for introduction of algorithms that use level as a base and modifies it in formulas that use other elements	PressureLevel = {Light} LightRange = 1.0 - 3.0 Will send control commands to Tactile Engine to deliver pressure in range from 1-3, with exact number determined by algorithm, which may take B/N data as input
PulseDivisions	Defines number of pulses in each basic division	Allows for introduction of algorithms such that pressure can be applied in timed groups with pauses or emphasis on given beats	PulseDivisions = 2 PulseDivisionType = Pulses PulseDivisionArray = [4,4] PulseDivisionVocabularyPressure = [{Light, Medium}, {Medium, Heavy}] Could result in 2 divisions, each 4 pulses long. In first division, pulses used will be Light and Medium Pressure level.
Pulse Type	Defines type of pulse	Allows for introduction of algorithms that can take advantage of Tactile Engine's ability to deliver different types of pressure	PulseType = {sequential} A "smart glove" with pressure delivery capability at each finger could have a "sequential" delivery setting, where pulses are delivered to each finger in sequence, or an "all" setting, where pulses are delivered to all fingers at once.
Temperature	Defines temperature at pressure delivery point	Allows for introduction of algorithms that can take advantage of Tactile Engine's ability to deliver different temperatures	Temperature = {neutral} A Smart Back massager may have a built in hot-pad capability, such that along with the pressure delivery points there is a surrounding pad that can be set to a certain temp.

Fig. 25

2600

Name of TCCS Parameter	Description	Use of Parameters in Flavor/Scent Output	Use of Parameters
FlavorScent Category	Defines available Flavors and/or Scents	Allows for introduction of algorithms that can deliver Flavors or Scents of varying types	FlavorScentCategoryArray=[{Bitter}, {Sweet}] FlavorScentCategoryDetailArray=[{Lemon} {Sugar, Agave}] These are zero based associative arrays. The FlavorScentCategoryArray is a zero-based associative array, such that element n of this array is associated with element n of the FlavorScentCategoryArray. Hence element 1 of the FlavorScentCategoryArray (Sweet), has details of Sugar and Agave in the FlavorscentCategoryDetailArray
ScentFlavor Map	Defines which compartment in Flavor/Scent Engine contains which Flavor/Scent	Used by algorithms for sending command information to Flavor/Scent Engine	ScentFlavorMap=[{Lemon, 1}, {Tomato, 2}] Indicates Lemon is in compartment 1 and Tomato is in compartment 2

Fig. 26

2700

Creative Circuit	Description	Example Usage	Comment
Intrapersonal Mind ←-> Mind	Output sensory experience is a blend of Audio and Tactile	Setup system so pulse speed of back massager as well as flute volume level is determined by EEG Alpha power	The combination of audio and tactile sensory experience can give user very clear and powerful feedback
Interpersonal Musical Instrument ←-> Mind	Output sensory experience is a blend of EEG outputs from 1, 2 or more individuals and auditory characteristics of 1, 2 or more instruments, plus emitted scents	1 or multiple musicians with some or all wearing EEG headsets, multiple listeners with some or all wearing wrist heartrate monitors, EEG headsets, drum is driven by aggregated heart rate data, lavender scent driven by Aggregated EEG data (Theta power levels)	Scent will feedback on heartrate and EEG levels, as will drum. Easy measurement of these effects provides tool for research. Many combinations of sensory feedback modes and input modes can be tested

Fig. 27

2800

Sensory Experience Category	Examples of Elements of Vocabulary	Methods of Vocabulary formation	Examples of Delivery Mechanism
Sound	Pitch, velocity, attack, sustain, vibrato. (all parameters available from MIDI protocol, including MIDI control messages	Spectral analyzer, MIDI message monitor	Digital Audio Workstation (DAW), such as Logic
Sight	Angles{15, 20, 45}, Shapes{Circle, Triangle, Cube}, Colors{hue, saturation, chroma, size, velocity , direction (for animation)	Computer vision - object and shape recognition systems such as Python OpenCV library	Computer graphics, animation system such as Unity
Smell/Taste	Category (earthy, fruity, medicinal, minty, musky, smoky, etc.) and the corresponding chemical compounds, intensity	Olfactometry, Gas Chromatography Mass Spectrometry	"Smart" aroma delivery device, with capability to load chemicals needed to express vocabulary Smart" food/drink delivery device with capability to load food/drink sources to express vocabulary
Touch	Pressure, rate, temperature, wave type (smooth or choppy, circular)	Analysis of device control messages correlated with user feedback gather during use of Smart body stimulation device	"Smart" body stimulation device (back massager or glove) with capability to deliver pressure to points on the body to express vocabulary

Fig. 28

SYSTEM AND METHOD FOR CREATING A SENSORY EXPERIENCE BY MERGING BIOMETRIC DATA WITH USER-PROVIDED CONTENT

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims the benefit of U.S. Provisional Patent Application No. 63/334,309 filed Apr. 25, 2022 and is a continuation-in-part of U.S. patent application Ser. No. 17/659,600 filed Apr. 18, 2022, which is a continuation of U.S. patent application Ser. No. 16/872,940 filed May 12, 2020, which is now issued as U.S. Pat. No. 11,308,925 and claims the benefit of U.S. Provisional Patent Application No. 62/885,307 filed Aug. 11, 2019 and U.S. Provisional Patent Application No. 62/846,918 filed May 13, 2019, the entire contents of each of the foregoing applications being hereby incorporated by reference herein.

TECHNICAL FIELD

This application generally relates to biometric data, and more specifically, to creating a sensory experience using biometric and/or neurometric data and user-provided content.

BACKGROUND OF THE INVENTION

The increased availability of low-cost portable devices that capture biometric/neurometric input data has prompted a new generation of applications to become available to the general public. The terms biometric and neurometric are used herein to generally encompass all data that is derived from measurements taken of living organisms, whether this be pulse, blood pressure, or brain wave/electroencephalogram (EEG) data, for example. These terms are often used to refer to authentication and security mechanisms, but are used herein in a wider context. This data can now be utilized outside of clinical environments for purposes ranging from entertainment to fitness to health monitoring and diagnostics. Different bio/neurometric data sources can be merged, and devices can also be networked to create a new generation of data uses where the merged data of multiple individuals can be processed in real-time. An example of a new low end EEG system is the Muse 2016, a portable headset developed by Interaxon Corporation to capture both EEG and heart rate in real-time. Software applications have been written to process this data, such as the demonstration application that comes with the Muse system. This application, which runs on Android or iOS devices, is designed to help a person improve their meditation skills. Several other low end EEG systems are also available, some at lower price points than the Muse. These technological advances are putting EEG, Heart Rate Variability (HRV), and other forms of biometric/neurometric data capture in the hands of more individuals than was possible before. Accordingly, there is a need for systems and/or techniques configured to utilize this data in new and useful ways.

SUMMARY OF THE INVENTION

The invention is defined by the appended claims. This description summarizes some aspects of exemplary embodiments and should not be used to limit the claims. Other implementations are contemplated in accordance with the techniques described herein, as will be apparent to one

having ordinary skill in the art upon examination of the following drawings and detail description, and such implementations are intended to within the scope of this application.

Systems and methods are provided herein for using brain waves or other bio/neurometric data to enhance a sensory experience by forming a creative circuit between a user's mind and user-provided content. For example, the user may wear an EEG headset for detecting their own brain activity, or other equipment for collecting bio/neurometric (B/N) data from the user. The B/N data can be measured while the user is creating content, such as, e.g., speaking, singing, chanting, drawing, listening, etc., or experiencing an audio-visual event, such as, e.g., a live performance by another person, a pre-recorded performance, playback of an audio and/or video file, experiencing a tactile sensation such as getting a back massage, or a taste or smell sensation such as smelling a flower or eating an ice cream cone. Techniques described herein are used to create an enhanced sensory output (e.g., audible sound and/or visual data, a tactile experience, a flavor and/or scent experience, or any combination thereof) by merging or blending the user-provided content with corresponding EEG signals. For example, frequencies and overtones detected in the user-provided audio content can be used as the preferred notes for translating biometric data into musical tones. These techniques can be used in some cases to create a feedback loop while the user is producing music (or experiencing a musical performance) by modifying the output, in real time, as the user continues to produce content (or experience the performance), thus providing a customizable interactive sensory experience. In some cases, the enhanced sensory experience can be stored for future retrieval to allow the user to re-experience the event later. In some cases, the EEG signals can be obtained from one or more listeners, rather than the user/performer that is creating the content, and the modified or enhanced content is presented to the performer (e.g., musician). In other cases, the EEG signals of two people interacting with each other can be blended together and provided to each other as musical outputs or other sensory output. Various other uses cases are also possible, as described herein.

While the exemplary content above is music (and audio sensation), the invention can be applied to any of the five human senses. For example, the chemical makeup of given flowers can be analyzed, and the chemicals discovered can be isolated and used as the preferred scents for translating biometric data into scents. Similarly, the chemical makeup of a given beverage can be analyzed, and the chemicals discovered can be isolated and used as the preferred sources for translating biometric data into tastes. In the tactile realm, temperature settings, pressure levels as well as speed and rhythm of applied pressure used in, for example, an automated or manual back massager can be analyzed and used as the preferred set of temperatures, motions, rhythms, and pressures for translating biometric data into tactile experiences. Just as is the case with music, the techniques disclosed herein can, in some cases, be tailored to create a feedback loop while the user is having a sensory experience, such as, a back massage from a "smart" massage system, thus providing a customizable interactive sensory experience. The massage system may be "smart" in the sense of being capable of responding to electronic commands, delivered over a wired or wireless network connection, that control its delivery of heat and vibrations. For some use cases, the device must also be capable of providing its current parameters in real-time over a wired or wireless connection while in operation. In some cases, the enhanced sensory experience can be stored for future retrieval to allow the user to re-experience the event later. In some cases, the EEG signals can be obtained from one or more listeners, rather than the user/performer that is creating the content, and the modified or enhanced content is presented to the performer (e.g., musician). In other cases the EEG signals of two people interacting with each other can be blended together and provided to each other as musical outputs or other sensory output. In other instances, the B/N data of multiple people who are presented with a taste or smell can be used to create a new taste or smell experience that is the product of the blending of the B/N from these multiple participants, and this can be an iterative process. Various other use cases are also possible, as described herein.

One exemplary embodiment provides a method of creating a coherent output based on biometric and/or neurometric data using a computing device comprising one or more processors and memory. The method comprises receiving a first incoming signal from a first bio-generated data sensing device worn by a user; receiving, from a sensory input system, a first input signal representing sensory content experienced by the user in association with generation of the first incoming signal; using the one or more processors, populating a common vocabulary with one or more values determined based on the first input signal, the common vocabulary being stored in the memory; determining, using the one or more processors, a first set of output values based on the first incoming signal, the common vocabulary, and a parameter file stored in the memory, the common vocabulary comprising a list of possible output values, and the parameter file comprising a set of instructions for applying the common vocabulary to the first incoming signal to derive the first set of output values; generating, using the one or more processors, a first output array comprising the first set of output values; and providing the first output array to an output delivery system configured to render the first output array as a first sensory output.

According to some aspects, the first sensory output is a tactile output comprising vibrations determined based on the first output array, and the output delivery system comprises one or more vibration output devices for generating the vibrations. According to other aspects, the first sensory output is an aroma output having a scent determined based on the first output array, and the output delivery system comprises one or more scent output devices for generating the scent. In still other aspects, the first sensory output is a consumable item having a flavor determined based on the first output array, and the output delivery system includes one or more flavor output devices for generating the flavor.

According to one or more aspects, the sensory input system comprises a tactile input source, and the sensory content is vibratory content applied to the user, the first input signal including first data identifying a pressure level of the vibratory content and second data identifying a pulse rate of the vibratory content. According to some aspects, the sensory input system comprises a tactile input source, and the sensory content is tactile content that is applied to the user and comprises temperature and vibratory components, the first input signal including first data identifying a pressure level of the tactile content and second data identifying a temperature setting of the tactile content. According to other aspects, the sensory input system comprises a material analysis device, and the sensory content is a source material consumed by the user, the first input signal comprising data identifying one or more components of the source material.

According to some aspects, the first bio-generated data sensing device is a monitor configured to collect heart rate intensity or heart date variability data of the user. According to other aspects, the first bio-generated data sensing device is a headset configured to collect electroencephalography ("EEG") signals of the user.

According to one or more aspects, the method further comprises receiving a second incoming signal from a second bio-generated data sensing device worn by the user; determining, using the one or more processors, a second set of output values based on the second incoming signal, the common vocabulary, and the parameter file, wherein the parameter file further comprises a set of instructions for applying the common vocabulary to the second incoming signal; generating, using the one or more processors, a second output array comprising the second set of output values; and providing the second output array to the output delivery system, the output delivery system further configured to render the second output array as a second sensory output.

According to some aspects, the method further comprises receiving a second input signal, from an audio/visual input system, representing audio content produced by the user during receipt of the first incoming signal; populating the common vocabulary based further on the second input signal using a spectral analyzer and the one or more processors; determining, using the one or more processors, a third set of output values based on the first incoming signal, the common vocabulary, and the parameter file; generating, using the one or more processors, a third output array comprising the third set of output values; and providing the third output array to the output delivery system, the output delivery system further configured to render the third output array as an audio output. According to further aspects, the third set of output values comprises Musical Instrument Digital Interface ("MIDI") data.

According to one or more aspects, the first set of output values comprises output values corresponding to at least a first variable and a second variable, and determining the first set of output values comprises: selecting a first output value from the list of possible output values for the first variable based on a frequency band of the first incoming signal and the parameter file, and selecting a second output value from the list of possible output values for the second variable based on a power level of the first incoming signal and the parameter file. In some aspects, the first and second variables are configured to control rendering of an audio output, the first variable being pitch and the second variable being velocity. In other aspects, the first and second variables are configured to control rendering of a visual output, the first variable controlling shape and the second variable controlling angle. In other aspects, the first and second variables are configured to control rendering of a tactile output, the first variable controlling pulse speed and the second variable controlling pulse pressure. In other aspects, the first and second variables are configured to control rendering of a taste or smell output, the first variable controlling category of scent or taste and the second variable controlling intensity.

According to aspects, the first input signal includes a frequency component and a power component. In some aspects, the one or more values determined based on the first input signal include a pitch value determined based on the frequency component and a velocity value determined based on the power component. In other aspects, the one or more values includes a shape value and a color value determined based on the frequency component and an angle value determined based on the power component. In still other aspects, the one or more values include a pulse speed value based on the frequency component and a pulse pressure value based on the power component.

According to one or more aspects, the method further comprises receiving, from the input system, a set of input signals over a time period representing varying tactile content experienced by the first user in the form of temperature, pulse pressure, speed, and rhythm values that can be sent to the system from a "smart" tactile delivery system. The tactile delivery system can output the parameters as it is in operation. Various settings tried by the user can be used to dynamically create a vocabulary. These scenarios can be extended such that settings of the "smart" delivery devices discussed above can be correlated with biometric data gathered as the user is experiencing these sensations, and preferred settings can be chosen that illicit the target responses as indicated by user feedback and B/N data.

According to one or more aspects, the common vocabulary is populated with values determined based on different types of sensory experiences, the first input signal being associated with a first sensory experience, and the output array being associated with a second sensory experience that is different from the first sensory experience.

Another exemplary embodiment provides a system comprising a first bio-generated data sensing device worn by a first user and configured to detect a first electrical signal representing biometric and/or neurometric data of the first user; a sensory input system configured to provide a first input signal representing sensory content experienced by the user in association with detection of the first electrical signal; a memory configured to store a parameter file and a common vocabulary; one or more processors configured to: receive the first input signal from the sensory input system, populate the common vocabulary with one or more values determined based on the first input signal, determine a first set of output values based on the detected signal, the common vocabulary, and the parameter file, and generate a first output array comprising the first set of output values; and an output delivery system configured to render the first output array as a first sensory output, wherein the common vocabulary comprises a list of possible output values, and the parameter file comprises a set of instructions for applying the common vocabulary to the first electrical signal to derive the first set of output values.

According to some aspects, the bio-generated data sensing device is a headset configured to collect electroencephalography ("EEG") signals of the first user. According to other aspects, the bio-generated data sensing device is a monitor configured to collect heart rate intensity or heart date variability data of the user.

According to some aspects, the first sensory output is a tactile output comprising vibrations and/or temperature-related sensations (e.g., heat) determined based on the first output array, and the output delivery system comprises one or more vibration output devices configured to generate the vibrations and/or temperature output devices configured to generate the temperature-related sensations. In some aspects, the one or more vibration output devices are configured to generate vibrations with a specified temperature setting or level selected based on the first output array. According to other aspects, the first sensory output is an aroma output having a scent determined based on the first output array, and the output delivery system comprises one or more scent output devices for generating the scent. According to still other aspects, the first sensory output is a consumable item having a flavor determined based on the first output array, and the output delivery system includes one or more flavor output devices for generating the flavor.

According to some aspects, the sensory input system comprises a tactile input source, and the sensory content is vibratory content applied to the user, the first input signal including first data identifying a pressure level of the vibratory content and second data identifying a pulse rate of the vibratory content. According to some aspects, the sensory input system comprises a tactile input source, and the sensory content is temperature and/or vibratory content applied to the user, the first input signal including first data identifying a pressure level of the vibratory content and second data identifying a temperature level of the vibratory content. According to other aspects, the sensory input system comprises a material analysis device, and the sensory content is a source material consumed by the user, the first input signal comprising data identifying one or more components of the source material.

In some aspects, the input system comprises a gas-chromatography device to identify chemicals producing a given scent or taste, representing a smell and/or taste component of the user provided content.

According to one or more aspects, the output delivery system comprises a tactile engine configured to generate a tactile output signal based on the output array and provide said signal to a tactile sensation delivery device. In some aspects, the first set of output values corresponds to a plurality of tactile variables for rendering a tactile output, the tactile variables comprising temperature, pressure, speed, and rhythm.

According to one or more aspects, the system further comprises a second bio-generated data sensing device worn by the user and configured to detect a second electrical signal representing biometric and/or neurometric data of the user, wherein the one or more processors are further configured to: determine a second set of output values based on the second electrical signal, the common vocabulary, and the parameter file, wherein the parameter file further comprises a set of instructions for applying the common vocabulary to the second electrical signal; and generate a second output array comprising the second set of output values, and wherein the output delivery system is further configured to render the second output array as a second sensory output.

According to one or more aspects, the system further comprises an audio/visual input system configured to provide a second input signal representing audio content produced by the user during detection of the first electrical signal; and a spectral analyzer configured to identify one or more aspects of the second input signal, wherein the one or more processors are further configured to: populate the common vocabulary based further on the identified aspects of the second input signal; determine a third set of output values based on the first electrical signal, the common vocabulary, and the parameter file; generate a third output array comprising the third set of output values; and provide the third output array to the output delivery system, wherein the output delivery system is further configured to render the third output array as an audio output. According to further aspects, the third set of output values comprises Musical Instrument Digital Interface ("MIDI") data.

According to one or more aspects, the common vocabulary comprises a tactile vocabulary for selecting different tactile characteristics based on various aspects of the detected signal. Elements of the tactile vocabulary may be temperature, pressure, pulse speed, or pulse rhythm.

According to one or more aspects, the common vocabulary comprises a smell/taste vocabulary for selecting different smell or taste characteristics based on various aspects of the detected signal. Elements of the smell/taste vocabulary could be either subjective terms such as "bitter," "sweet," "salty," or "lavender," classes of elements or compounds such as "ketones," names for elements or compounds such as "iodine," names for foods such as "ginger," or aromatic substance names such as "violet."

Another exemplary embodiment includes a system, comprising a first bio-generated data sensing device worn by a first user and configured to detect a first electrical signal representing biometric and/or neurometric data of the first user; a second bio-generated data sensing device worn by a second user and configured to detect a second electrical signal representing biometric and/or neurometric data of the second user; a memory configured to store a parameter file and a common vocabulary; one or more processors configured to: determine a set of output values based on the first electrical signal, the second electrical signal, the common vocabulary, and the parameter file, and generate an output array comprising the set of output values; and an output delivery system configured to render the first output array as a first sensory output for the first user and a second sensory output for the second user, wherein the common vocabulary comprises a list of possible output values, and the parameter file comprises a set of instructions for applying the common vocabulary to each of the first electrical signal and the second electrical signal to derive the set of output values.

According to one or more aspects, the system further comprises a sensory input system configured to provide: a first input signal representing sensory content experienced by the first user in association with detection of the first electrical signal, and a second input signal representing sensory content experienced by the second user in association with detection of the second electrical signal, wherein the one or more processors are further configured to: receive the first and second input signals from the sensory input system, and populate the common vocabulary with one or more values determined based on the first input signal and the second input signal.

According to one or more aspects, each of the first bio-generated data sensing device and the second bio-generated data sensing device is a headset configured to collect electroencephalography ("EEG") signals or the is a monitor configured to collect heart rate intensity or heart date variability data.

While certain features and embodiments are referenced above, these and other features and embodiments of the invention will be, or will become, apparent to one having ordinary skill in the art upon examination of the following figures and detailed description. It is intended that all such additional embodiments and features included within this description, be within the scope of the present invention, and be protected by the accompanying claims.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention can be better understood with reference to the following drawings. The components in the drawings are not necessarily to scale, emphasis instead being placed upon clearly illustrating the principles of the present invention. In the drawings, like reference numerals designate corresponding parts throughout the several views.

FIG. **1** is a block diagram depicting an exemplary creative circuit system for capturing bio/neurometric data and producing a coherent output based thereon, in accordance with embodiments.

FIG. **2** is a block diagram depicting an exemplary creative circuit module configured for real-time processing of captured bio/neurometric data and producing a coherent output based thereon, in accordance with embodiments.

FIG. **3** is a block diagram depicting an exemplary creative circuit module configured for "playback" processing of previously-recorded bio/neurometric data and producing a coherent output based thereon, in accordance with embodiments.

FIGS. **4**A and **4**B are flowcharts depicting exemplary operations for concurrently processing multiple threads of bio/neurometric data using a common, pre-defined vocabulary and parameter file and producing coherent musical outputs based thereon, in accordance with embodiments.

FIG. **5** is a block diagram depicting an exemplary creative circuit system for creating a feedback loop, in accordance with embodiments.

FIG. **6** is block diagram depicting another exemplary creative circuit system for creating a feedback loop, in accordance with embodiments.

FIG. **7** is a block diagram depicting an exemplary creative circuit system for creating a feedback loop while two users are interacting with the system, in accordance with embodiments.

FIG. **8** is a block diagram depicting an exemplary creative circuit system for creating a feedback loop while two users are interacting with the system and experiencing a live performance, in accordance with embodiments.

FIG. **9** is a block diagram depicting an exemplary creative circuit system comprising multiple bio/neurometric data collection devices for gathering data simultaneously and output devices for presenting a combined, coherent, visual and audible output to the user based thereon, in accordance with embodiments.

FIG. **10** is a flowchart depicting exemplary operations for concurrently processing multiple threads of bio/neurometric data using a common vocabulary derived from spectral analysis of live audio input, and simultaneously producing coherent video and audible outputs based thereon, in accordance with embodiments.

FIG. **11** is a flowchart depicting exemplary operations for mapping bio/neurometric data to appropriate audio representations using parameter file and vocabulary datastore, in accordance with embodiments.

FIG. **12** is a flowchart depicting exemplary operations for mapping bio/neurometric data to appropriate visual representations using parameter file and vocabulary datastore, in accordance with embodiments.

FIG. **13** is a flowchart depicting exemplary operations for creating a feedback loop while a single user is creating audio content and listening to an audio output generated based on the audio content and bio/neurometric data obtained from the user while performing, in accordance with embodiments.

FIG. **14** is a block diagram depicting an exemplary creative circuit system for processing multiple input sources using targeting logic, in accordance with embodiments

FIG. **15** depicts a table describing exemplary parameters in a parameter file that may be used to generate audio and/or video outputs, in accordance with embodiments.

FIGS. **16**A, **16**B, and **16**C depict a table describing exemplary parameters that may be used by a processing plug-in to generate audio and/or video outputs, in accordance with embodiments.

FIGS. **17**A and **17**B depict a table describing example uses of a creative circuit system, in accordance with embodiments

FIG. **18** depicts the contents of an exemplary parameter file, in accordance with embodiments

FIG. **19** is a block diagram depicting a system comprising an exemplary creative circuit module configured to collect bio/neurometric data and produce coherent output based thereon in various sensory formats, in accordance with embodiments.

FIG. **20** is block diagram illustrating aspects of the system of FIG. **19** for evaluating source materials, in accordance with embodiments.

FIG. **21** is a block diagram illustrating aspects of the system of FIG. **19** for evaluating and producing scents and/or flavors, in accordance with embodiments.

FIG. **22** is schematic diagram illustrating interaction of a user with a tactile production module of the system of FIG. **19** to generate a unique tactile sequence, in accordance with embodiments.

FIG. **23** is a schematic diagram illustrating use of the tactile production module of FIG. **22** with multiple users to combine tactile input data, in accordance with embodiments.

FIG. **24** depicts a table describing exemplary parameters in a parameter file that may be used to generate tactile, flavor, or scent outputs, in accordance with embodiments.

FIG. **25** depicts a table describing exemplary parameters that may be used by a processing plug-in to generate tactile outputs, in accordance with embodiments.

FIG. **26** depicts a table describing exemplary parameters that may be used by a processing plug-in to generate flavor or scent outputs, in accordance with embodiments.

FIG. **27** depicts a table describing example uses of a creative circuit system, in accordance with embodiments.

FIG. **28** depicts a table describing example aspects of different sensory vocabulary components and their creation, in accordance with embodiments.

DETAILED DESCRIPTION

The description that follows describes, illustrates and exemplifies one or more particular embodiments of the present invention in accordance with its principles. This description is not provided to limit the invention to the embodiments described herein, but rather to explain and teach the principles of the invention in such a way to enable one of ordinary skill in the art to understand these principles and, with that understanding, be able to apply them to practice not only the embodiments described herein, but also other embodiments that may come to mind in accordance with these principles. The scope of the present invention is intended to cover all such embodiments that may fall within the scope of the appended claims, either literally or under the doctrine of equivalents.

Embodiments described herein include a system that allows biometric/neurometric data (also referred to herein as "bio/neurometric data") to be transformed into audio and visual artistic and/or therapeutic works, and/or other sensory experiences, such as tactile experiences, flavor experiences, scent experiences, or any combination thereof, including a capability to adjust to brain responses in real-time, thus producing an audio, visual, tactile, scent, flavor, and/or other sensory output that becomes more and more impactful, as the user (or users) learn what brain waves produce their favorite results and control the output consciously or unconsciously, for example. This interaction between the system and the user can be described as creating a circuit, hence the name Creative Circuit. The system may be part of a suite of tools introduced under the name Theta-u, hence the name Theta-u Creative Circuit System (TCCS).

The advances described above also lay the groundwork for merging different biometric data sources, and networking multiple devices to create a new generation of bio/neurometric data uses where the data of multiple individuals can be processed in real-time and output in the form of sound, images, or other sensory output modes. In order to allow these new network-enabled capabilities to produce a coherent, useful result, a common structure underlying the multiple streams of data is provided. For example, multiple individuals can wear EEG headsets, and the data coming from these headsets can be processed in a manner that produces sound which varies in pitch or amplitude according to the brain waves, as described for instance in U.S. Pat. No. 10,369,323, and/or visual stimuli with the generated images varying according to the fluctuations in EEG data. But if such a configuration was created and the resulting audio or video stream played or displayed, it is likely that the result would be chaotic and with limited usefulness, since the likelihood that these multiple streams would produce a coherent audio or visual result is quite low. For our purposes, we describe audio or visual stimuli as "coherent" when it conforms at least loosely to one of the concepts we use to process sound and images in a given culture, either as music or language in the case of audio, or as an image, or with geometric consistency or symbolic association in the case of images. Even within one stream, the result in our example would not have a structure which we would find coherent in this sense, since it would conform to none of the rules we have formed for music or language or meaningful visual images for our particular culture.

The system described here provides that underlying structure that will make streams of output data both internally coherent and coherent with one another, through the mapping of the bio/neurometric data to a tactile, flavor, scent, sonic, and/or visual "vocabulary." The term vocabulary is usually used in connection with simply words or phrases, but can also be used in an artistic sense, as in a musical vocabulary. For instance, when jazz musicians improvise against a song, they are often following a set of rules which dictate what chords and tones are meant to be stressed at each point in the song. Simplified, a song might be in the key of D, and in that case the pitch "vocabulary" of the song centers around the tones of the D major scale: D, E F#, G, A B C#. Similarly, the system described herein maps bio/neurometric data to a sonic vocabulary which is expressed as a collection of musical pitches (or a set of possible values for the pitch variable), as well as via harmonic and rhythmic element, as well as a visual vocabulary which is expressed as a collection of shapes, colors and angle (or a set of possible values for each of these variables). The concept can be applied as well to tactile sensory experiences, where the vocabulary can be expressed as, for instance, a collection of vibrational pressure levels, delivery rates, and temperature settings, or a flavor/scent sensory experience, where the vocabulary can be expressed, for instance, as a collection of flavor categories (e.g., "bitter", "salty," etc.) or as a collection of elements or compounds that have particular scents or flavors. Using this system, multiple individuals could wear the EEG headsets as described above, and produce a musically coherent merged result. Also, a single individual could process different data streams, each emanating from just one person, and produce a coherent result. The system also provides a mechanism for mapping bio/neurometric data to a visual or image vocabulary which is expressed as a collection of visual symbols, shapes, dimensions, angles, or other geometric constructs. Using this system, multiple individuals could wear the EEG headsets as described above, and produce a musically and visually coherent merged result. Also, a single individual could process different data streams, each emanating from just one person, and produce a musically and visually coherent result. In the same manner, the system provides a mechanism for mapping bio/neurometric data to a tactile or flavor/scent vocabulary.

Regarding creation of audio textures, the human ear can hear frequencies in the approximate range of 20 hertz (Hz) to 18 kilohertz (kHz). We start with the principle that given an x and y axis, with x being time, all time series data can be made into frequency data in this range by performing a function on the y axis values that transforms the data into this range. For instance, an EEG system might record frequency at an electrode site of 3 Hz (e.g., determined by Fast Fourier Transform (FFT) from raw EEG). By applying a scale factor, this rate can be transformed into a range within human hearing range, for instance, by multiplying by 100 to get a 300 Hz value. Any y-axis data can be used, not just EEG frequency. For example, suppose we are plotting raw EEG time series data, where the y-axis is power in microvolts (μV) of a signal at a given electrode site on the scalp. If the average values are in the range 0.3 μV to 1.5 μV, again we can apply a scale factor to bring these numbers into, for example, the range 51-880 hertz (Hz), or the frequency range A1 to A5 on a piano keyboard, and use the resulting values as frequency data to drive a piece of music. The values could even be outside of the realm of bio/neurometric data, such as, for example, data plotting stock prices or foreign exchange rates of currency pairs. Any time series data can be transformed by a scaling function and used as frequency data. Similarly, for production of visual textures, a data point in a time series can be interpreted as a visually accessible data value, such as, a point on a line, or a color or a rotation.

By applying these principles for audio and visual transformations, bio/neurometric time series data can be translated into for instance a creative animation that is synchronized with the audio component with the same data source driving the creation. Once an individual or groups' brain activity is rendered as auditory or visual stimuli in this manner, it can influence both the person/people producing the output and others, creating feedback loops as an individual responds to his own rendered brain output which changes his thought process which in turn changes the output. This is what we refer to as a Creative Circuit. The system described herein implements this concept through software-based processing of signals from one or more bio/neurometric data capture devices combined with audio and/or visual input, and linking these input streams via a common "vocabulary" creating output signals that can be rendered as audio or video textures that form a coherent whole when played or viewed together. The examples provided herein should be taken only as examples to illustrate how the system allows for any type of sensory vocabulary (e.g., audio, visual, tactile, flavor, and/or scent) included as an input source to be mapped to the same or a different sensory vocabulary on the output side through a transformation supported by the software architecture.

The generality of the system, allowing it to process multiple different forms of bio/neurometric data, comes from two main architectural features: the provision for use of custom parameters which can represent any domain value or type of data desired, for instance, heart rate in the case of HRV data and microvolts (μV) in the case of EEG power, combined with use of a "plug-in" architecture that allows custom functions to be written to handle this arbitrary bio/neurometric data. The examples given in this document illustrating, for instance, a function to calculate pitch from EEG power, should not be taken to be any more than examples, to show possible embodiments of the invention.

According to embodiments, the vocabulary described herein may be stored in a vocabulary database that is either pre-populated (i.e. static) with a common vocabulary, or dynamically populated with a real-time vocabulary based on an analysis of incoming data, audio and/or visual (e.g., from a live performance). In the case of static vocabulary, the vocabulary datastore information may be stored or held in the parameter file and may be represented by arrays of notes, for example, or a list of possible output values for each variable represented in the vocabulary. In the case of real-time vocabulary, the vocabulary datastore information may be stored or held in a separate file capable of being dynamically populated or updated, such as, for example, a JSON file containing JSON arrays, with each JSON object representing a note. Which vocabulary datastore implementation is chosen can be based on system requirements, such as, e.g., performance and ease of access. In some embodiments, the vocabulary datastore may be implemented as a database, such as, e.g., relational, document-oriented, or other suitable database types.

FIG. **1** depicts an exemplary creative circuit system **100** configured to capture bio/neurometric data from a user and produce a coherent audio and/or visual output based thereon, in accordance with embodiments. As shown, the creative circuit system **100** (also referred to herein as "Theta-u creative circuit system" or "TCCS") comprises at least one bio/neurometric (or B/N) data collector **102** and at least one bio/neurometric data receiver **104** communicatively coupled to the data collector **102** for receiving a data feed therefrom. The exact number of data collectors **102** and data receivers **104** may be depend on the number of users simultaneously using the creative circuit system **100** and/or a functional capacity of the system **100**. The creative circuit system **100** further comprises a computing device **106** communicatively coupled to the B/N data receiver **104** for processing bio/neurometric data obtained from the (or each) data receiver **104** and generating an output based thereon. In some embodiments, the computing device **106** can be configured to simultaneously process multiple streams of data from multiple users, and produce a combined output based on all said streams.

The B/N data collector **102** (also referred to herein as a "bio-generated data sensing device") is configured to capture or detect electrical signals representing a biometric and/or neurometric response of a user (e.g., human) wearing the data collector **102**, or otherwise connected thereto. The B/N data collector **102** can be implemented in hardware, software, or a combination thereof, and can include any type of device or system capable of capturing an input representing bio-generated data, or biometric and/or neurometric data, such as, for example, heart rate, galvanic skin response, brain wave/EEG activity, muscle movement, eye movement, blood pressure, breath measurements, or the like.

For example, in some embodiments, the B/N data collector **102** includes an electroencephalography (EEG) system, including electrodes configured for placement along the scalp of a wearer, for sensing and recording an electrical activity of the brain of the wearer. In some cases, the B/N data collector **102** may include one or more systems for collecting data related to heart activity, such as, e.g., a photoplethysmography (PPG) system, including a light source and a photodetector configured for placement at the surface of the wearer's skin, for measuring and monitoring a heart rate of the wearer, and/or a pulse oximetry system, including a probe configured for placement on a finger, ear lobe, or other suitable body part, for measuring an oxygen level in the blood of the wearer. In some instances, the PPG system may also be used to measure a breathing activity of the wearer. In some cases, the B/N data collector **102** may include one or more accelerometers for detecting muscle and other body movements of the wearer. In some cases, the B/N data collector **102** may include all of the above-listed biometric data collection systems and devices, or any other combination thereof. In one exemplary embodiment, the B/N data collector **102** is an EEG headset that captures EEG data and other biometric data of a user wearing the headset, such as, for example, the "Muse 2" headset manufactured by Interaxon Corporation.

The B/N data collector **102** is further configured to transmit the captured signals to the B/N data receiver **104** using a wired or wireless connection (e.g., Bluetooth, WiFi, and the like). In a preferred embodiment, the data collector **102** uses Bluetooth technology to send the data feed to the data receiver **104**. The B/N data collector **102** may include a communications module configured to communicate with the B/N data receiver **104**. For example, said communications module may include one or more transmitters, receivers, antennas, modems, and other circuitry for carrying out the communication features described herein.

The B/N data receiver **104** is configured to receive a data feed from the data collector **102** and provide the received data to the computing device **106**. The B/N data receiver **104** (also referred to as a "receiver node") can be implemented in hardware, software, or a combination thereof, and can be any type of electronic device or system with an interface capable of communicating with the B/N data collector **102** and processing the received data. For example, the B/N data receiver **104** may be a mobile or portable device (e.g., smartphone, smartwatch or other connected wearable device, personal digital assistant (PDA), MP3 player, gaming device, tablet, laptop computer, etc.), or a non-portable or stationary electronic computing device (e.g., a desktop computer, a server computer, etc.). In a preferred embodiment, the B/N data receiver **104** is a smartphone operating on an Android platform from Google, Inc. In other embodiments, the data receiver **104** may be a smartphone operating on iOS from Apple Inc., Windows Phone from Microsoft Corporation, Symbian from Nokia Corporation, or other suitable platform or operating system.

In some embodiments, the B/N data receiver **104** is configured to store and/or execute a software application **122** for interfacing with the B/N data collector **102** and receiving bio/neurometric data therefrom. In some cases, this software application **122** is proprietary software provided by the makers of the particular B/N data collector **102** being used. In other cases, the software application **122** may be a readily-available, third-party application configured for use with an existing biometric data collection device, such as, e.g., the "Mind Monitor Application" designed for use with the Interaxon Muse headset, which is shown and described at the web site "mind-monitor.com", the contents of which are incorporated by reference herein. In still other embodiments, the software application **122** may be novel software developed for use with any type of B/N data collector **102** connected to the creative circuit system **100**.

Though not shown in FIG. **1**, the B/N data receiver **104** may include a memory configured to store the software application **122**, a processor configured to execute the application **122**, and a communications module configured to communicate with the B/N data collector **102** and the computing device **106**, as well as other components for carrying out the operations described herein. The communications module, in particular, may include one or more transmitters, receivers, antennas, modems, and other circuitry for carrying out the communication features described herein.

The B/N data receiver **104** can be configured to transmit the bio/neurometric data received from the B/N data collector **102** to the computing device **106** using an appropriate communication protocol. In a preferred embodiment, the data receiver **104** transmits this data to the computing device **106** over a WiFi network using an Open Sound Control (OSC) protocol, which is shown and described at the website "opensoundcontrol.org/introduction-osc". the contents of which are incorporated by reference herein. Other types of wireless or wired communication protocols compatible with transmitting bio/neurometric data in real-time (or near real-time) may also be used, as will be appreciated.

Likewise, the computing device **106** can be communicatively coupled to the B/N data receiver **104** via a wired connection (e.g., USB, Ethernet, or other data cable) or a wireless connection (e.g., WiFi, Bluetooth, cellular, or other wireless technology). The computing device **106** may include a communications module (not shown) configured to communicate with the B/N data receiver **104**. For example, said communications module may include one or more transmitters, receivers, antennas, modems, and other circuitry for carrying out the communication operations described herein.

According to embodiments, the computing device **106** comprises a creative circuit module **108** configured to process the received bio/neurometric data of the user and determine an output based thereon. The creative circuit module **108** may include one or more software applications and/or programming code comprising a set of instructions to be performed by one or more processors **124** of the computing device **106** in order to implement steps and/or elements for carrying out the techniques described herein.

The computing device **106** may be any type of electronic device capable of supporting the creative circuit module **108** or otherwise processing the bio/neurometric data received via the data receiver **104**. For example, the computing device **106** may be a desktop computer, a server computer, a laptop computer, a tablet, or the like. In one embodiment, the computing device **106** is a Mac Pro computer from Apple, Inc. In other embodiments, the computing device **106** may be implemented as a distributed computing system comprising a plurality of computers or other computing devices in communication with each other over a network. In another embodiment, the computing device **106** and the B/N data receiver **104** may be integrated into one device configured to receive the bio/neurometric data directly from the B/N data collector **102**, process the same, and generate an output based thereon.

In some embodiments, the computing device **106** is configured to operate as a network server that uses the creative circuit module **108** (also referred to as a "TCCS server application") to simultaneously process multiple streams of bio/neurometric data of various users. For example, the computing device/network server **106** may include an interface configured to communicate with multiple B/N data receivers **104** (or receiver nodes) at once, each data receiver **104** conveying bio/neurometric data received from a separate B/N data collector **102**.

According to embodiments, the creative circuit module **108** may include logic for receiving the incoming bio/neurometric data and may use one or more algorithms (for example, as specified by processing plug-in **206** shown in FIG. **2**), in conjunction with a parameter file and a vocabulary datastore, to process the incoming data. The vocabulary datastore can be shared by multiple threads or streams of incoming data to produce an output, which can then be rendered as audio and/or video. In some cases, the creative circuit module **108** may also include an aggregation component (e.g., within TCCS harness **202** shown in FIG. **2**) for processing and/or combining multiple data streams before producing the output.

In some embodiments, the creative circuit module **108** also receives audio and/or visual inputs (also referred to herein as "user-provided content") from an audio/visual input system **109** included in the system **100** and is configured to incorporate those inputs into its output. For example, as shown in FIG. **1**, the input system **109** may comprise an audio input device **110**, such as, e.g., a microphone or other audio device for capture audio data or signals generated by, or otherwise associated with, the user. As also shown, the input system **109** may also comprise a visual or video input device **112**, such as, e.g., a camera, video recorder, webcam, or other video device for capturing images, video, or other visual data generated by or associated with the user.

In such cases, the creative circuit module **108** may be configured to apply algorithms, as described herein, to map the received bio/neurometric data to the received audio and visual representations using a vocabulary datastore and parameter file, send resulting instructions to an audio/visual output delivery system **113**, and modify metadata to change the processing behavior of these algorithms in real-time based on the incoming data. In some cases, the audio/visual inputs may represent live data being recorded by the input system **109** and streamed to the creative circuit module **108** in real-time (or near real-time), such as, e.g., a live vocal (e.g., singing, spoken word, etc.) and/or musical performance being produced by the user, or being produced by another individual and experienced by the user. In other cases, the audio/visual inputs may represent previously-recorded data that was captured by the same devices, or data stored in a memory of the input system **109** and/or the computing device **106**, such as, e.g., playback of an audio track or video file.

In some embodiments, the input system **109** comprises a plurality of audio input devices **110** and/or a plurality of visual input devices **112** and is configured to record and/or stream live audio and/or video from multiple sources (or users). In such cases, the multiple data streams may be sent to the aggregation component of the creative circuit module **108** before being processed further.

In some cases, the audio input device **110** and the visual input device **112** may be combined into a single device, such as, e.g., a video camera or the like. In other cases, each of the audio input device **110** and the visual input device **112** may operate independently and therefore, may have a separate connection to the computing device **106**, as shown. Either way, each of the audio input device **110** and the visual input device **112** may be communicatively coupled to the computing device **106** using a wired (e.g., USB, etc.) or wireless (e.g., Bluetooth, WiFi, cellular, etc.) connection.

In other embodiments, one or more of the audio input device **110** and visual input device **112** may be included in the B/N data receiver **104** or communicatively coupled thereto. In such cases, the B/N data receiver **104** may transmit the bio/neurometric data feed to the computing device **106** along with the audio/visual data feed using one or more appropriate communication protocols, and the creative circuit module **108** may be configured to receive and process both types of data. In still other embodiments, one or more of the audio input device **110** and the visual input device **112** may be included in the computing device **106**, for example, as a native microphone and/or camera system.

The audio/visual output delivery system **113** can be configured to receive signals from the creative circuit module **108** or other components of the computing device/network server **106**, and render audio and/or visual outputs in accordance with those signals. The output delivery system **113** may include at least one of an audio output device **114** for playing an audio output (e.g., music, voice, etc.) and a visual output device **116** for displaying a visual output (e.g., images, videos, etc.). Delivery via these devices **114** and **116** may be the last step in providing an audio and/or visual output according to the signals sent to the output system **113** by the creative circuit module **108**.

In embodiments, one or more components of the output delivery system **113** may be included within the computing device **106**, or may be communicatively coupled thereto, as shown in FIG. **1**. For example, in some embodiments, the visual output device **116** may be an external monitor communicatively coupled to the computing device **106** (e.g., via an HDMI cable or the like). In other embodiments, the visual output device **116** may be a native display screen of the computing device **106**, or otherwise integral thereto. Likewise, in some embodiments, the audio output device **114** may be an external speaker system or personal listening device communicatively coupled to the computing device **106** (e.g., via an audio cable or a wireless connection, such as Bluetooth). In other embodiments, the audio output device **114** may be native or internal speakers of the computing device **106**, or otherwise integral thereto.

As also shown in FIG. **1**, the output delivery system **113** further comprises one or more processing components for generating the audio and/or visual output according to the instructions supplied by the creative circuit module **108**. In particular, an audio production module **118** may be configured to generate an audio output and provide it to the audio output device **114** in order to play the audio output for the user. Likewise, a graphics/animation engine **120** may be configured to generate a visual output and provide it to the visual output device **116** in order to display the visual output for the user. These components may be implemented in hardware, software, or a combination thereof. In some embodiments, the audio production module **118** and/or the graphics/animation engine **120** may be integrated into, or form one of the components of, the creative circuit module **108**, such as, e.g., audio/visual engine **619** shown in FIG. **6**.

In some embodiments, the creative circuit module **108** is configured to generate corresponding Musical Instrument Digital Interface ("MDI") data based on the received B/N data feed and send instructions to the audio production module **118** in MIDI format. The audio production module **118** is configured to process the incoming MIDI data and generate an appropriate audio output signal based thereon. And the resulting audio output signal is played back to the user via the audio output device **114**. In one embodiment, the audio production module **118** may be implemented using a digital audio workstation, such as, e.g., Logic Pro by Apple Inc., or other compatible software program for recording, editing, and/or producing audio files, including MIDI files.

As an example, the MIDI format instructions generated by the creative circuit module **108** may specify parameter values for channel (e.g., 0 to 15), pitch (e.g., 0 to 127), and velocity (e.g., 0 to 127), and may indicate control of a note length by sending "note_on" and "note off" instructions, or the like. For example, the note may begin playing once the NoteOn message is received and may continue to play until the NoteOff message is received, thus setting the length of the note. The velocity value may be indicated as a separate variable sent with the NoteOn message (e.g., velocity=90). Tempo may also be set by a separate temp variable to include the speed of a quarter note, as will be appreciated. In some embodiments, the channel parameter allows a processing plug-in of the creative circuit module **108** to instruct the audio production module **118** to play different tones on different software instruments. For example, channel 1 may be assigned to a saxophone, channel 2 to a piano, channel 3 to a drum, etc. As a result, in embodiments that include a plurality of B/N data collectors **102**, each data collector **102** can be mapped to a different channel, such that the B/N data of each user can be represented by a different instrument or sound in the audio output produced by the system **100**.

The creative circuit module **108** may also generate visual output data and use the Open Sound Control ("OSC") protocol, or other communication protocol, to send the visual output data to the graphics/animation engine **120**. This engine **120**, in turn, may be configured to convert the OSC to a visual representation. For example, the graphics/animation engine **120** may be configured to use a library designed to handle OSC data to receive the visual output data provided by the creative circuit module **108** and provide custom logic to render this data as moving geometric designs. One example of such a library is shown and described in the website found at "thomasfredericks.github.io/UnityOSC/", the contents of which are incorporated by reference herein. In some embodiments, each receiver node/data receiver **104** may establish a connection to the network server/computing device **106** using User Datagram Protocol ("UDP") or other appropriate communications protocol, and may send the bio/neurometric data to the network server **106** using the OSC protocol. In one embodiment, the graphics/animation engine **120** is a Unity engine comprising software written in C# programming language.

As shown in FIG. **1**, the computing device **106** comprises one or more processors **124** and memory **126**. In some embodiments, the one or more processors **124** and memory **126** may be dedicated to carrying out operations associated with the creative circuit module **108**, as illustrated. In other embodiments, the processor(s) **124** and memory **126** may be part of the larger computing device **106**, and memory **126** may be configured to store the creative circuit module **108**, or the software used to implement said module **108**, along with other software.

The one or more processors **124** can be a hardware device for executing software, particularly software stored in the memory **126**. For example, during operation of the creative circuit module **108**, the processor(s) **124** may be configured to retrieve software instructions stored in memory **126** for implementing the creative circuit module **108**, and execute the same to carry out desired operations. The processor(s) **124** can be any custom made or commercially available processor, such as, for example, a Core series or vPro processor made by Intel Corporation, or a Phenom, Athlon or Sempron processor made by Advanced Micro Devices, Inc. In the case where computing device **106** is a server, the processor(s) **124** may be, for example, a Xeon or Itanium processor from Intel, or an Opteron-series processor from Advanced Micro Devices, Inc. The one or more processors **124** may also represent multiple parallel or distributed processors working in unison.

Memory **126** can include any one or a combination of volatile memory elements (e.g., random access memory (RAM, such as DRAM, SRAM, SDRAM, etc.)) and non-volatile memory elements (e.g., ROM, hard drive, flash drive, CDROM, etc.). It may incorporate electronic, magnetic, optical, and/or other types of storage media. Memory **126** can have a distributed architecture where various components are situated remote from one another, but are still accessed by processor(s) **124**. These other components may reside on devices located elsewhere on a network or in a cloud arrangement.

Software stored in memory **126** may include one or more separate programs. The separate programs comprise ordered listings of executable instructions for implementing logical functions. In embodiments, memory **126** may be configured to store software instructions for implementing the creative circuit module **108**. Such software may be written in any suitable computer programming language, such as, e.g., C, C++, C#, Pascal, Basic, Fortran, Cobol, Perl, Java, Ada, Python, and Lua, or a proprietary language developed to interact with these known languages. In a preferred embodiment, the creative circuit module **108** comprises one or more software applications written in Python.

Various components of the system **100** shown in FIG. **1** may be implemented using software executable by one or more servers, computers, or other computing devices using a processor and a memory included therein, such as, e.g., the processor(s) **124** and memory **126** shown in FIG. **1**. In addition, some aspects of the invention described herein may be implemented through interactions between the various components of the system **100**, the interactions also being facilitated by software executing on one or more computer processors associated with said components. As an example, FIGS. **2** and **3** illustrate exemplary software components that may be used to implement some of these interactions with the creative circuit module **108** of the system **100**. Other software components may also be used, as will be appreciated.

FIG. **2** illustrates an exemplary creative circuit module **200** comprising various software components for implementing real-time processing of incoming bio/neurometric data and live user-provided content, in the form of audio and/or video data, production of a coherent output based thereon, and recording of the received data for playback at a later time, in accordance with embodiments. The creative circuit module **200** may be representative of the creative circuit module **108** shown in FIG. **1**. As shown, the creative circuit module **200** (also referred to as a "TCCS module") comprises a processing harness **202**, a bio/neurometric data listener **204**, a processing plug-in **206**, an audio engine **208**, a visual engine **210**, and a file manager **212**. The creative circuit module **200** may also include other components not shown in FIG. **2**, such as, e.g., an aggregation component.

In embodiments, the processing harness **202** (also referred to as a "TCCS harness") may be a software component configured to coordinate the activities of the other underlying components of the module **200**. In particular, the processing harness **202** may be configured to initialize the creative circuit module **200** based on pre-defined parameters (also referred to as "TCCS parameters") stored in a parameter file, start an input data stream (e.g., by instructing the bio/neurometric data listener **204** to start receiving bio/neurometric (B/N) data from a user and/or sending received data to the harness **202**), dispatch or send the received bio/neurometric data to the processing plug-in **206**, receive an output array (also referred to as "OutputArray") generated based on the received data from the processing plug-in **206**, and send the output array to the audio engine **208** and the visual engine **210** for output generation.

The B/N data listener **204** is configured to receive bio/neurometric data from source equipment worn by a user, such as, e.g., the B/N data collector **102** shown in FIG. **1** and described herein, or other B/N data collection device. As shown, the B/N data listener **204** is further configured to send the received data to the processing harness **202** as an input data stream, in order to make the data available for real-time processing. The B/N data listener **204** also sends the received data to the file manager **212** in order to write the data to a file for future analysis and processing.

The processing plug-in **206** is configured to receive bio/neurometric data from the processing harness **202**, analyze each incoming data sample, create appropriate output data values based on the analysis of the input data and an application of the parameters stored in the parameter file, and produce an output array comprising values configured to describe the output to be rendered.

The audio engine **208** is configured to receive the output array, or more specifically, an audio output array comprising values configured to describe the audio output to be rendered, from the processing harness **202**, and render an appropriate audio output based thereon. The audio output array may include MIDI values selected based on the received B/N data, as described herein. In some embodiments, the audio engine **208** includes a preconfigured multitrack setup that receives the MIDI instructions and converts them into sound in accordance with the instrumentation choices included in the MIDI file. In some embodiments, the audio engine **208** may be the audio production module **118** shown in FIG. **1** and may be in communication with the audio output device **114** for delivery of the audio output to the user. In other embodiments, the audio engine **208** may be configured to communicate the audio output array to the audio production module **118**, which in turn renders the audio output via the audio output device **114**.

Likewise, the video engine **210** is configured to receive the output array, or more specifically, a visual output array comprising values configured to describe the visual output to be rendered, from the processing harness **202**, and render an appropriate visual output based thereon. In some embodiments, the video output may be a preconfigured scene that is driven by data values included in the video output array. For example, the video output array may include data driving parameters, such as, e.g., line length, color, animation speed, object size, and field of view, for changing an appearance of the preconfigured scene based on the received B/N data.

The file manager **212** can be configured to implement file reading and writing services to enable data to be recorded. Said data may be retrieved later, for example, during operation in a playback mode, as shown in FIG. **3**. As shown, the file manager **212** may comprise a bio/neurometric data reader **214** (also referred to herein as "data recorder") for capturing and recording the real-time data stream received from the bio/neurometric data listener **204**. In some embodiments, the data recorder **214** is also configured to record user-provided content received via, for example, the audio input device **110** and/or visual input device **112** shown in FIG. **1**.

FIG. **3** illustrates an exemplary creative circuit module **300** comprising various software components for implementing "playback" processing of previously-recorded bio/neurometric data and user-provided content, in the form of audio and/or video data, and production of a coherent output based thereon, in accordance with embodiments. The creative circuit module **300** may be representative of the creative circuit module **108** shown in FIG. **1** and may be substantially similar to the creative circuit module **200** shown in FIG. **2**, except for the absence of a bio/neurometric data listener. In some embodiments, the creative circuit module **200** may be configured to operate like the creative circuit module **300** shown in FIG. **3** during a playback processing and only operate as shown in FIG. **2** during real-time processing.

As shown in FIG. **3**, the creative circuit module **300** comprises a processing harness **302** configured to coordinate the activities of underlying components, similar to the harness **202**. In particular, the processing harness **302** may be configured to initialize the creative circuit module **300** based on pre-configured TCCS parameters, open an input file stream (e.g., by requesting the file from file manager **312**), dispatch or send bio/neurometric (B/N) data samples to processing plug-in **306**, receive an output array from the same, and send the output array to audio engine **308** and visual engine **310**.

The file manager **312** can be configured to send a requested file containing pre-corded B/N data to the processing harness **302**. The file manager **312** may include a bio/neurometric data reader **314** configured to implement read access to previously recorded B/N data files. In some embodiments, the file manager **312** may have acquired the B/N data files by recording live input data streams, like the file manager **212** shown in FIG. **2**.

The processing plug-in **306** included in the creative circuit module **300** can be configured to receive B/N data from the processing harness **302** and create output data values based on an analysis of the input data and an application of the parameters in the TCCS parameter file and appropriate vocabulary from the vocabulary datastore, like the processing plug-in **206** shown in FIG. **2**. The output values can be provided to the processing harness **302** as an output array describing the audio and/or visual output to be rendered.

The audio engine **308** of the creative circuit module **300** receives the output array from the processing harness **302**, or an audio output array portion thereof, and renders an audio output based thereon, similar to the audio engine **208**. The audio output array can include MIDI values or instructions that are plugged into a preconfigured multitrack setup included in the audio engine **308**. This setup renders sound according to the instrumentation choices in the received MIDI file.

Likewise, the visual engine **310** is configured to receive the output array from the processing harness **302**, or more specifically a visual output array portion thereof, and render a visual output based thereon, similar to the video engine **210**. The video engine **310** may include a preconfigured scene that can be driven by the received output data. For example, the visual output array may include data driving parameters such as, e.g., line length, color, animation speed, object size, and field of view.

FIG. **4**A illustrates an exemplary process **400** for concurrently processing multiple threads or streams of bio/neurometric data using a common predefined vocabulary and parameter file, in accordance with embodiments. The process **400** may be carried out using one or more components of a creative circuit module, such as, e.g., the module **200** shown in FIG. **2**, or using any computing device having corresponding software stored on a computer readable medium and executable by one or more computer processors. While FIG. **4**A specifically shows concurrent processing of data streams obtained from two separate human subjects, it should be appreciated that the incoming data of three or more human subjects may be concurrently processed using similar techniques.

As shown, the process **400** may begin with a bio/neurometric data listener **402**, such as, e.g., the data listener **204** shown in FIG. **2**, providing the incoming data streams or threads from individual human subjects to a TCCS dispatcher **404**, such as, e.g., the TCCS harness **202** shown in FIG. **2**. The data listener **402** may be configured to make multiple connections to multiple data collection devices (such as, e.g., B/N data collector **102** shown in FIG. **1**), and hence multiple human subjects.

The TCCS dispatcher **404** assigns a respective one of a plurality of processing plug-ins **406** and **408** to each human subject and provides the corresponding thread to the identified processing plug-in ("PPI"). As shown, each plug-in **406**, **408** also receives parameters from a TCCS parameter file **410**, which may provide common pitch and/or rhythm data, or vocabulary, to be used for both threads. As shown, the process **400** enables concurrent processing of both data threads, thus producing simultaneous outputs that are musically coherent.

As shown, the TCCS system (e.g., creative circuit module **200/300**) makes use of parameter files, consisting of name-value pairs, where the value could be a list or a primitive value. An exemplary parameter file **1800** is shown in FIG. **18**, for the sake of illustration only. In some cases, a global parameter file is shared by the whole system and is configured to define a common vocabulary to be used by all. For example, FIG. **4**A illustrates an embodiment in which the parameter file **410** comprises a vocabulary datastore from which the common vocabulary can be derived, and multiple threads are able to access the same parameter file **410**, via processing plug-ins **406** and **408**, to make use of the information contained in the file **410**.

In some embodiments, each thread can also have its own private parameter file where different parameters are defined, such as, e.g., MIDI channel mappings and log file name. For example, data may be logged separately for each thread in its own log file for troubleshooting purposes, and different MIDI channels may be selected for each thread by including corresponding data values in each private parameter file. In FIG. **4**A, for instance, the data for a first human subject (or a first thread) may be fed to a first MIDI channel, which is assigned to a first instrument (e.g., cello), and the data for a second human subject (or a second thread) may be fed to a second MIDI channel, which is assigned to a second instrument (e.g., piano). The processing plug-ins **406** and **408** for both threads can then use the common vocabulary datastore to create a coherent musical output from these threads, such as, for example, a piano-cello duet in the key of D. In such cases, each processing plug-in **406**, **408** may provide a separate audio output to the audio engine, and the audio engine can be configured to produce the outputs as individual musical tracks which are played simultaneously to create a single, merged output (e.g., the piano-cello duet). In other embodiments, the data for both threads can be provided to the same MIDI channel, and thus, assigned to the same instrument, and the audio engine can be configured to merge the two audio streams into one audio track (e.g., a piano-piano duet).

FIG. **4**B illustrates an exemplary process **420** that may be used by one of the concurrently running processing plug-ins **406**, **408** to process incoming data, in accordance with embodiments. Each processing plug-in may receive input data from a given human subject that includes bio/neurometric data, as well as user-provided content, in some cases (such as audio and/or video data). As shown, the process **420** may begin at step **422** with setting vocabulary from the global parameter file (e.g., TCCS parameter file **410**), or retrieving the vocabulary terms (or variables) that will be used to render an output based on the incoming B/N data. In the illustrated embodiment, the vocabulary originates from a vocabulary datastore that is included in the parameter file, for example, as shown in FIG. **4**A. In such cases, the parameter file may include a collection of variables or data fields representing the common vocabulary. For example, the parameter file may include an array of notes (or "preferredNotesArray"), arranged in name, value pairs, that represents the pitch vocabulary, thus defining the pitches that will be used in the PPI to select a note for incoming data, using the algorithms described herein.

In embodiments, the vocabulary datastore may be implemented as a list, table, or database configured to store a plurality of variables and associated data fields for representing different vocabulary. As an example, in some embodiments, the vocabulary datastore may be a relational database, such as, e.g., MySQL, or document oriented, such as, e.g., Mongo. In some cases, the contents of the vocabulary database may be static, or pre-populated based on human/user input, in order to develop a common vocabulary for all data threads. In such cases, the vocabulary datastore may be included in the common parameter file, for example, as shown in FIG. **4**A. In other cases, the contents of the vocabulary database may be dynamically populated in real-time based on spectral analysis of user-provided content, for example, as shown in FIG. **10**. In such cases, the vocabulary datastore may exist separately from the parameter file, as also shown in FIG. **10**. As an example, the vocabulary datastore may be stored in a file using JSON format or other format that allows vocabulary to be populated in real-time.

The vocabulary datastore may include pitch vocabulary and rhythm vocabulary, in some embodiments. The pitch vocabulary may include, for example, data fields (or name, value pairs) configured to define a first tonal center (or "Tonal Center 1") representing a D major scale (or the key of D) with pitches D, E, F# (or sharp), G, A, B, C# (or sharp), and a second tonal center (or "Tonal Center 2") representing an A major scale (or the key of A) with pitches A, B, C sharp, D, E, F# (or sharp), and G# (or sharp). The rhythm vocabulary may include, for example, data fields configured to define four preset segments (also referred to herein as "divisions") for creating a 4 by 4 (or 4/4) time signature (also known as "common time"), and within each segment, data fields to define a number of seconds per note (e.g., each quarter note could have a duration of 0.5 seconds for segment 1, 0.75 seconds for segment 2, and 0.5 seconds for segment 3, for example, as represented by the array {0.5, 0.75 0.5}). In some embodiments, the processing plug-ins **406**, **408** may use the rhythm vocabulary to assign different speeds to different EEG bands based on the parameters in the parameter file (e.g., quarter notes may represent samples in the Alpha range, eighth notes may represent samples in the Beta range, etc.)

As shown in FIG. **4**B, the vocabulary datastore may also store other types of vocabulary for creating the musical or other audio output, such as, e.g., a melody vocabulary, a harmony vocabulary, etc. In addition, the vocabulary datastore may include one or more types of image vocabulary for creating a visual output.

Referring back to FIG. **4**B, step **424** of the process **420** includes selecting one or more values from the rhythm vocabulary based on the input B/N data. For example, the input B/N data may consist of a sample in the Alpha range, and the parameter file **410** may indicate that the speed of a quarter note for this segment should be 0.4 seconds. Thus, the processing plug-in algorithm may be coded such that Alpha data is rendered as eighth notes, resulting in a calculated note length of 0.2 seconds.

Step **426** includes selecting one or more values (e.g., pitch values) from the pitch vocabulary based on the input data, for example, using techniques described herein (e.g., process **1100** shown in FIG. **11**). The process **420** may also include, at step **428**, selecting one or more values (e.g., melody values) from the melody vocabulary based on the input data. As will be appreciated, pitch refers to a single note, while a melody is composed of multiple notes played sequentially and thus, denotes at least 2 notes. In some embodiments, the melody value selected from the melody vocabulary may depend on the pitch value selected from the pitch vocabulary. For example, the melody value may include the pitch selected at step **426** plus at least one of a first pitch that is sequentially before the selected pitch and a second pitch that is sequentially after the selected pitch, or other combination of multiple pitches that forms a musical phrase (e.g., a melodic fragment) comprising the pitch selected at step **426**. Other algorithms or techniques for selecting melody values are also contemplated, such as, for example, playing the note that is a half-step above or below the pitch selected at step **426**, along with the selected pitch.

The process **420** may further include, at step **430**, selecting one or more values from the harmony vocabulary based on the input data. In some embodiments, the harmonic values may be selected based on the pitch value(s). For example, based on a collection of pitches, a set of chords can be determined which contain those pitches and thereby, form the harmonic vocabulary. The harmonic vocabulary can be derived either from the result of spectral analysis (e.g., as shown in FIG. **10**) or defined statically (e.g., as in FIG. **4**A), indicating the chords corresponding to each time segment that are musically coherent with the pitch set for that segment. For example, spectral analysis may be used to produce the following JSON array with pitches in order of amplitude or volume {"F", "A", "D", "B", "A", "C#"}, which may be stored as the pitch vocabulary in the parameter file **410**, and based thereon, the processing plug-in may analyze the data in pairs and produce chord candidates (e.g., by matching pitches F and A to chord F Major, matching pitches D and B to chord B minor, and matching pitches A and C# to chord A Major).

At step **432**, the process **420** includes selecting one or more values from the image vocabulary based on the input data, for example, using techniques described herein (e.g., process **1200** shown in FIG. **12**). It should be appreciated that in some embodiments, the process **420** may not include one or more of the steps **424** through **432** if the corresponding vocabulary is not included in the vocabulary set at step **422** after analyzing the parameter file, for example.

At step **434**, the process **420** includes outputting the selected audio and visual representations, or the values selected in steps **424** through **432**, to audio and/or visual engines, as appropriate. This may be shown in, for example, FIG. **2**, by the audio engine **208** receiving an audio output array from the processing plug-in **206** via the TCCS harness **202**, and the visual engine **210** receiving a visual output array from the same.

To avoid hard-wiring of methods and algorithms and allow maximum flexibility, the system supports a plug-in architecture (e.g., processing plug-ins **406** and **408**), where new code can be easily inserted to process new data streams or accommodate new purposes (for example, as shown in FIG. **10**). The configurable nature of the plug-in architecture is illustrated in FIG. **15**, for example, which provides examples to show how values in the TCCS parameter file can determine which targeting plug-in, processing plug-in, audio engine, and video or visual engine to use. As will be appreciated, other architectures may be used to implement the techniques described herein.

To illustrate what an exemplary plug-in might look like, FIGS. **16**A-**16**C depict a table **1600** describing an exemplary set of parameters, and showing how these parameters could be used within the exemplary processing plug-in. This example illustrates how multiple threads of execution executing the provided code with a common parameter file can result in a coherent audio/visual result. In table **1600**, the parameters may be used in the audio output to influences data values passed to the sound generation system, for instance, using MIDI, OSC, or other audio streaming protocols. Likewise, the parameters may be used in the video output to influence data values passed to the visual generation system, for instance, using OSC or other streaming data protocols. The usage examples provided in the last column of table **1600** use variable names defined in other parameter examples within the same column, showing possible ways parameters can be used in formulae with one another (i.e. not hard-wired). It should be assumed that each function is called in a loop (e.g., called at least once for each sample. For purposes of simplicity, it should also be assumed that all variables are Global in Scope. The "defined parameters" mentioned in table **1500** may refer to the parameters listed in table **1600**, according to embodiments.

Below is an exemplary pseudo-code implementation of processing plug-in logic flow to show that the process (e.g., process **400** and/or process **420**) can accommodate real-time stream of EEG and other bio/neurometric data, in accordance with embodiments. The below-mentioned custom parameters "C1-C10" are present to accommodate any arbitrary purpose including neurometric/biometric data values that may be produced by B/N data collection devices other than an EEG headset, such as, for example, a respiration measurement device (e.g., as provided by Spire Health) or other wearable breath tracker, or a blood pressure monitor. In some embodiments, the "PluginChoice" value may be obtained as specified in table **1500** of FIG. **15**, and the "TCCS Parameters" may be obtained as specified in table **1600** of FIGS. **16**A, **16**B, and **16**C. The exemplary pseudo-code may include the following operations:

```
With (real-time biometric data stream)
For each record x in data stream)
    A=alphaEEGpower
    B=betaEEGpower
    G=gammaEEGpower
    T=thetaEEGpower
    D=deltaEEGpower
    H=heartRate
    C1-C10=CustomBioMetric1-CustomBioMetric10
    rawEEG=RawEEGpower
outputArray=ApplyPlugIn (PluginChoice, TCCSParameters, A, B, G, T, D, H, C1-C10, RawEEG)
SendData (audio engine, video engine, outputArray)
Loop until data stream closed or end command received.
```

In the above, it should be understood that "Alpha" refers to brainwaves (or EEG power) with a frequency band or range of 8-12 hertz (Hz), "Beta" refers to brainwaves in a frequency range of 12.5-30 Hz, "Gamma" refers to brainwaves in a frequency range of 25-140 Hz, "Theta" refers to brainwaves in a frequency range of 4-7 Hz, and "Delta" refers to brainwaves in a frequency range of 0.5 to 4 Hz. In embodiments, the creative circuit module may be configured to analyze the incoming signal to determine which of these frequency bands are included in signal. The identified frequency bands are then used to determine which pitch values and other output values are included in the output array for rendering a coherent output. For example, in some embodiments, an output array may be generated in which each EEG band is associated with, or assigned to, a different MIDI channel or instrument (e.g., Alpha=flute, Beta=violin, etc.), and the MIDI pitch number for each channel may be derived based on the frequency of each EEG band and the overtones in the user-provided content (or the vocabulary developed based thereon).

In some embodiments, the processing plug-in may use different pitch selectors for different EEG bands. For example, the pitch selector method for the Muse 2 EEG headset may call methods that calculate what pitch to produce for Alpha EEG bands differently than for Beta EEG bands. In the below example, the custom parameter C1 contains an array of 127 elements representing all possible MIDI pitch levels, with each array entry indicating the volume detected of a frequency matching that pitch (i.e. the real-time pitch vocabulary). The following pseudo code shows a possible flow of such processing plug-in logic:

```
def processingplugin(bioData)
    processDivisions( )
    processNoteLength( )
    setPitchForAlpha(bioData[alpha], biodata[C1])
    setPitchForBeta(bioData[beta], biodata[C1])
```

As an example, the algorithm for the above setPitchForAlpha method may include (1) create a list of all pitches in the live audio input that have volumes above a certain threshold or level, rank ordered by volume (e.g., an array in JSON file format), said pitches being identified using, for example, spectral analysis as described in FIG. **10**, (2) add said list to the current list represented in the "TonalCenter1" variable in the TCCS parameter file (or as a key variable of that file) and remove any repeats in pitch values to create a merged list, and (3) derive a MIDI pitch value for biodata [alpha] (or the given band of the EEG signal) using the newly populated TonalCenter1 as the key variable and by a mathematical transformation that is similar to that described above. This algorithm may be repeated for each band of the EEG signal (e.g., Alpha, Beta, Theta, etc.). It should be appreciated that in other embodiments, the setPitchforAlpha algorithm may be written to append to a different variable, such as, e.g., "TonalCenter2". In some embodiments, each EEG band may be appended or added to a different variable (e.g., Alpha to TonalCenter1 and Beta to TonalCenter2), such that the MIDI pitch values for each EEG band are derived based on different lists. Also, while the above example describes creating a list, in other embodiments, the method may populate the pitch vocabulary with the new data by creating an array of pitch values (represented as MIDI note numbers) and corresponding volume levels at step 1 and appending said array to the current array at step 2, or otherwise merging the two arrays.

In embodiments, standard audio signal processing techniques may be used to extract any desired characteristic of an audio stream representing user-provided content, and then provide the extracted data to the processing plug-in, as real-time vocabulary. In this manner, the user-provided content can influence the output of the algorithm for converting the brain waves to audible sound, thus creating a creative circuit where the user is influenced by the coherent output generated based on their brain waves.

FIG. **5** illustrates an exemplary creative circuit system **500** configured for creating a feedback loop while being used by a human subject (or user) **501**, in accordance with embodiments. As shown, the system **500** comprises a bio/neurometric (B/N) data collecting headset **502** worn by the user **501** and output devices for presenting a coherent, visual and audible output to the user based on the data collected by the headset **502**. As also shown, the output devices include an audio output device **514** for delivering an audible or audio output to the user **501** and a visual output device **516** for delivering a visual or video output to the user **501**. In embodiments, a feedback loop may be created by continuously updating the visual and/or audio outputs based on the real-time bio/neurometric data feed received via the B/N data collection headset, the real-time data feed including one or more "feedback signals," or B/N data representing a response of the user upon experiencing each audio and/or visual output.

The components of the system **500** may be substantially similar to corresponding components of the creative circuit system **100** shown in FIG. **1** and therefore, will not be described in detail here for the sake of brevity. For example, the B/N data collection headset **502** may be substantially similar to the B/N data collector **102**, the B/N data receiver **504** may be substantially similar to the B/N data receiver **104**, the computing device **506** may be substantially similar to the computing device **106**, and the creative circuit module **508** may be substantially similar to the creative circuit module **108**. Also, the audio production module **518** and the graphics/animation engine **520** may be substantially similar to the audio production module **118** and graphics/animation engine **120**, respectively. In one embodiment, the B/N data collection headset **502** may an EEG headset manufactured by Interaxon corporation (such as, e.g., the Muse 2 headset).

Moreover, like the audio output device **114**, the audio output device **514** may be external to the computing device **506** (e.g., external speakers, personal listening device, etc.), as shown in FIG. **5**, or may be integrated into the computing device **506** (e.g., as native/internal speakers). And like the visual output device **116**, the visual output device **516** may be an external display screen coupled to the computing device **506** (e.g., computer monitor), as shown in FIG. **5**, or may be integral to the computing device **506** (e.g., a laptop or desktop computer). In one embodiment, the visual output device **516** and audio output device **514** may be integrated into one unit, such as, e.g., a television or the like. In some embodiments, the system **500** may be implemented using the system **100**, for example, by forgoing the audio and visual input devices **110**, **112**.

During operation, the user **501** may experience an output generated by the computing device **506** by viewing the visual portion of the output using the visual output device **516** and/or listening to the audio portion of the output using the audio output device **514**. This experience may influence a thought process of the user **501**, which can be registered or captured by the B/N headset **502** as EEG data or other bio/neurometric data (also referred to herein as a "feedback signal"). The headset **502** can be configured to collect the feedback and other electrical signals from the user **501** wearing the device and send the captured human activity to the B/N data receiver **504** (e.g., over a Bluetooth network connection). The data receiver **504** can be configured to transmit the received data feed to the computing device **506**, for example, over a WiFi connection using the Open Sound Control (OSC) communication protocol (OSC). The creative circuit module **508** can be configured to process the incoming data and produce a new output array (also referred to herein as a "feedback output array") using algorithms specified in a processing plug-in and in conjunction with a parameter file and vocabulary datastore, for example, as shown in FIG. **4**A and described herein. The output array may be provided to the audio production module **518** (or "audio engine") and the graphics/animation engine **520** (or "visual engine") in order to generate a new audible output for delivery to the user via the audio output device **514** and a new visual output for delivery to the user via the visual output device **516**, respectively. This creates a feedback loop, as the user's mind, and therefore the EEG data feed, is again influenced by the new audio and/or visual content.

FIG. **6** illustrates another exemplary creative circuit system **600** configured to create a feedback loop for a person or user **601** wearing a B/N data collection headset **602** while experiencing an audio/visual output presented by the system **600**. In embodiments, the feedback loop may be created by continuously updating the visual and/or audio outputs based on the real-time bio/neurometric data feed received via the B/N data collection headset **602**. The system **600** may be substantially similar to the system **500** of FIG. **5**, except that the computing device **606** includes a single audio/visual engine **619** for generating the audio and/or visual outputs, rather than the dedicated audio engine and visual engine shown in FIG. **5**. Accordingly the common components of the system **600** will not be described in detail here for the sake of brevity.

In embodiments, the audio/visual engine **619** may be configured to receive an output array from the creative circuit module **608** comprising audio and visual output information selected based on the incoming B/N data, as described herein. In some embodiments, the audio/visual engine **619** may be implemented using existing visual programming software for creating real-time audiovisual works, such as, for example, Max/MPS/Jitter provided by Cycling '74, or other interactive media software capable of working with the creative circuit module **608** to present a coherent, visual and audible output to the user **601** based on the data collected by the headset **602**.

FIG. **7** illustrates an exemplary creative circuit system **700** configured to create a feedback loop while being used by two people: a first user **701** wearing a first B/N data collection headset **702** communicatively coupled to a first B/N data receiver **704**, and a second user **703** wearing a second B/N data collection headset **705** communicatively coupled to a second B/N data receiver **707**, in accordance with embodiments. The feedback loop may be created by collecting bio/neurometric data while the two users are experiencing an audio/visual output presented by the system **700**, and continuously updating that output based on the data collected from both users.

The system **700** may be substantially similar to the system **500** of FIG. **5**, except for the addition of a second user and the additional devices associated therewith. Accordingly, the common components of the system **700** will not be described in detail here for the sake of brevity. The B/N data collection headset **705** may be substantially similar to the B/N data collection headset **702** worn by the first user **701**, such as, e.g., a Muse 2 headset. The B/N data receiver **707** may also be substantially similar to the B/N data receiver **704** of the first user **701**. For example, both data receivers **704** and **707** may be Android smartphones. In other embodiments, the data receiver **707** may be another type of smartphone (e.g., an Apple iPhone) or a different type of electronic device (e.g., a gaming device, etc.). In either case, the data receiver **707** may be communicatively coupled to both the B/N data collection headset **705** (e.g., via a Bluetooth connection) and to a computing device **706** (e.g., via a WiFi connection) in order to convey the captured B/N data to a creative circuit module **708** included in the computing device **706**.

Using techniques described herein, the creative circuit module **708** may be configured to generate an output based on the B/N data received from both users, and provide an output array to an audio production module **718** and/or a graphics/animation engine **720** for delivering updated audio and/or visual outputs to both users via one or more of audio output deice **714** and visual output device **716**. For example, the creative circuit module **708** may use a common vocabulary and parameter file to analyze the individual data streams obtained from each of the users **701** and **703**, and may combine the results of that analysis to obtain a common output for delivery to both users.

FIG. **8** illustrates an exemplary creative circuit system **800** configured to create a feedback loop a first user **801** is listening to, or otherwise experiencing, a live performance produced by a second user **803**, in accordance with embodiments. The feedback loop may be created by collecting bio/neurometric data from the two users during the live performance, generating an output (audio and/or visual) based on the B/N data of both users, as well as live input data representing the live performance, then presenting the output to the users, and continuously updating that output as new B/N data and/or live input data is received. In some cases, the second user **803** may only receive an audio output representing feedback from the first user **801**, or the listener of the second user's performance. In such cases, the visual output may only be provided to the first user **801** in order to enhance the first user's sensory experience.

Other than the addition of a musical instrument **811** and an audio input device **810**, the system **800** may be substantially similar to the system **700** of FIG. **7** and may use similar techniques to create the feedback loop. Accordingly, the common components of the system **800** will not be described in detail here for the sake of brevity.

As shown in FIG. **8**, the creative circuit system **800** comprises a computing device **806** configured to receive, via a first B/N data receiver **804**, live bio/neurometric data collected by a first B/N data collection headset **802** from the first user **801**, and live bio/neurometric data, via a second B/N data receiver **807**, collected by a second B/N data collection headset **805** from the second user **803**. The system **800** also comprises audio input device **810** (e.g., a microphone, similar to the audio input device **110** shown in FIG. **1**) for capturing audio associated with the live performance and providing the captured audio signals as the live audio input. In the illustrated embodiment, the live performance is provided by the second user **803** playing musical instrument **811**, such as, e.g., a guitar, piano, cello, violin, drums, etc. In other embodiments, the live performance may be spoken word or other vocal performance provided by any one of the users and captured by the audio input device **810**.

The computing device **806** comprises a creative circuit module **808** configured to process the live audio input received via the audio input device **810** and the two live B/N data streams received via the data receivers **804** and **807**, and based thereon, generate an output for simultaneous delivery back to one or more of the users **801** and **803**. The output may be an audio output for delivery via an audio output device **814**, similar to the audio output device **714**. In some cases, the output may also include a visual output for delivery via a visual output device **816**, similar to the visual output device **716**.

In embodiments, the creative circuit module **808** may be configured to analyze the live audio input data using spectral analysis and create a vocabulary of pitches and/or rhythms based thereon, which then becomes the common vocabulary used by the algorithm that processes the biometric/neurometric data from both subjects (e.g., process **400** shown in FIG. **4**A and/or process **420** shown in FIG. **4**B). In some embodiments, the creative circuit module **808** uses an audio processing software tool for performing audio and/or music analysis in order to create the pitch vocabulary, for example, as an array representing the set of overtones in an incoming audio stream, binned into MIDI pitch buckets (e.g., written in JSON file format). The overtones may be derived from, or obtained based on, a frequency component extracted from the incoming audio stream by a spectral analyzer (e.g., spectral analyzer **1012** shown in FIG. **10**), and the overtones may be converted to MIDI pitches using a known mathematical algorithm. In one embodiment, the audio processing tool utilizes the LibROSA library and Python programming language to perform music information retrieval on the incoming audio data, for example, as shown and described at the website "musicinformationretrieval.com/chroma.html", the contents of which are incorporated by reference herein. For example, the LibROSA library may be used to identify pitch values and/or other aspects of the user-provided content (e.g., as shown in FIG. **13**). In some cases, the LibROSA beat module may be used to extract rhythm information from the user-provided content. Through such techniques, a "Vocabulary" datastore can be created in real time that defines the pitch and/or rhythm vocabulary to be used in the algorithm, which is configured to convert the incoming B/N data to sound, thereby allowing the audio output that is created based on both users' B/N data to be musically coherent and in harmony with the output produced by the musical instrument **811**.

Another example of usage involving live audio input relates to the practice of "humanization." This is an active topic in the field of electronic music, for example, as shown and described at the web site "makingmusic.ableton.com/humanizing-with-automation-envelopes", the contents of which are incorporated by reference herein. Synthesizers can be programmed with preset loops that allow a user to have, for instance, a drum track running and play along with the track. The problem with these loops, however, is the robotic sound, which misses the little variations that human drummers naturally introduce. Some modern music work stations offer "humanization" functions, which essentially involve adding random variations to the preset loop.

In embodiments, the creative circuit module **808** can be configured to take humanization to a new level, where the variations are controlled by brain waves rather than being random. In such cases, the computer-generated preset loops can be modified to conform to the same common vocabulary and can be "humanized" through brain-wave controlled variations. As an example, these techniques can be implemented in a group setting with two users or human subjects playing musical instruments, or for a single user setting where the person is playing solo but now has a lively backing track varied by his brain, instead of a drum machine playing behind him, as is conventional. As another example, the humanized music may be played on its own as a new musical piece.

In some embodiments, the user may load preset MIDI tracks into a digital audio workstation (or audio engine), such as, e.g., Logic, and may configure the workstation to play the MIDI tracks in a loop using a selected instrument, such as, e.g., a piano, so as to serve as a backing track that is continuously on repeat during the user's performance (e.g., second user **803**). Such preset loop may be received as an audio input at the audio input device **810** and may be spectrally analyzed to create the common vocabulary in real-time. In such cases, the system **800** may be configured to produce a humanized version of the preset loop by generating an output based in the common vocabulary derived from the preset loop, the brain waves collected from the user while the preset loop was playing, and the parameter file, using the techniques described herein. In other cases, the system **800** may be configured to generate an output based on the second user's live performance as shown in FIG. **8**, and said output may be added to, or played along with, the backing track for humanization purposes. For example, a flute may be used to play the brain wave-embellished MIDI track, while the original MIDI track may be played on the piano. In other embodiments, the system **800** may be configured to humanize the backing track based on a static vocabulary and the detected brain waves of one or more users. In each of above-described examples, the humanized backing track may be generated based further on the parameter file. For example, the parameter file may be configured to match the length of a quarter note with the corresponding setting for the preset loop. Further, in some cases, one or more settings of the system **800** may be adjusted so that the pitches produced by the brain waves embellish the backing track in a satisfying manner.

FIG. **9** illustrates using an exemplary creative circuit system **900** configured to simultaneously gathering various types of bio/neurometric data from a given user and produce a combined, coherent output based on all incoming data streams, in accordance with embodiments. As shown, the system **900** includes a plurality of bio/neurometric (B/N) data collection devices **902***a*, **902***b*, and **902***c* and a plurality of bio/neurometric (B/N) data receivers **904***a*, **904***b*, and **904***c*, each data receiver **904** communicatively coupled to a respective data collection device **902** (e.g., via a wired or wireless connection) for receiving a separate data feed therefrom. Each of the data receivers **904***a*, **904***b*, and **904***c* may also be communicatively coupled (e.g., via a wired or wireless connection) to a computing device **906** in order to transmit the received data thereto for processing. The computing device **906** includes a creative circuit module **908** configured to individually process the multiple data streams and generate a coherent output based on all received data. In embodiments, the system **900** may be substantially similar to the system **100** shown in FIG. **1** and described herein, aside from the addition of multiple B/N data collectors and data receivers. Accordingly, the common components of the system **900** will not be described in detail here for the sake of brevity.

In embodiments, each of the B/N data collection devices **902***a*, **902***b*, and **902***c* may be configured to collect a different type of bio/neurometric data from the user. For example, a first data collection device **902***a* may be configured to collect EEG data or other data representing brainwave activity, such as, e.g., a Muse 2 headset. A second data collection device **902***b* may be configured to collect breathing rate and/or heart rate data, such as, e.g., a Spire respiration monitoring device. A third data collection device **902***c* may be configured to collect cerebral oxygenation data or otherwise monitor tissue oxygenation, for example, using near-infrared spectroscopy ("NIRS"). Other types of bio/neurometric data collection devices may also be used, in addition to or instead of the above, in order to collect other types, such as, for example, respiration measurement devices, blood pressure monitor, pulse monitor, near-infrared EEG device, conventional EEG device, heart rate variability ("HRV") monitor, and the like. In some embodiments, one or more types of data collection devices may be combined into a single unit for ease of use and user comfort, for instance. In some embodiments, the system **900** may include more, or fewer, than the three data collection devices **902** shown in FIG. **9**.

The B/N data receivers **904***a*, **904***b*, and **904***c* may be any type of electronic device capable of receiving and processing the respective incoming data feed, such as, e.g., a smartphone, tablet, or other computing device, similar to the B/N data receiver **104** shown in FIG. **1**. In some embodiments, each data receiver **904***a*, **904***b*, **904***c* may be configured to handle the particular type of B/N data being collected by the corresponding data collection device **902***a*, **902***b*, **902***c*. For example, the first data receiver **904***a* may include a software application configured to receive and process EEG data, like the software application **122** shown in FIG. **1**. In one embodiment, the software application may be the Mind Monitor application designed to work with Muse 2 headsets.

The B/N data receivers **904** may use the OSC protocol, or other appropriate communication protocol, to transmit the received data feeds to the computing device **906**. If the native data collection component(s) for a given data receiver **904** do not support OSC, a translation layer may be added to the component(s) to convert the protocol supported by said receiver **904** to OSC.

Once the computing device **906** receives the B/N data from the data receivers **904***a*, **904***b*, and **904***c*, e.g., at a communications module of the computing device **906**, similar to the computing device **106** of FIG. **1**, the data may be provided to the creative circuit module **908**. The creative circuit module **908** may be configured to route each incoming data stream to the processing plug-in ("PPI") that has appropriate capabilities to support the respective data collection device **902** and/or type of data. In some embodiments, the creative circuit module **908** may use the following code to select or identify an appropriate PPI: <DeviceType/DeviceModel><OutputType>Selector. For example, if the B/N data collection device **902***a* is the Muse 2 EEG headset, the code to support this device would be named "EEGMuse2PitchSelector," "EEGMuse2RhythmSelector," "EEGMuse2Melody Selector," "EEGMuse2HarrmonySelector," "EEGMuse2ImageSelector," and so forth. Likewise, the code to support the Spire respiration monitor device would be "RespSpirePitchSelector," "RespSpireRhythmSelector," and so forth.

Through these codes, algorithms can be implemented which use the incoming data, the parameter files, and the vocabulary datastore to determine what audio and visual output to render. The output data is sent to an audio engine) **918** (similar to the audio production module **118**) and/or a visual engine **920** (similar to the graphics/animation engine **120**), depending on whether the output data is visual and/or audio. The visual engine **920** may be, for example, Unity or other graphics/animation production software, and the audio engine **918** may be, for example, Logic Pro or other digital audio workstation. The visual engine **920** can also contain custom code for image generation, for example, through the capability to add modules in the C# language to Unity. The visual engine **920** can also have access to the parameter files and vocabulary datastore and can also contain logic for image selection and geometric figure rendering. The audio engine **918** can be configured so that the input is rendered for different instruments on different MIDI channels, and these software instruments (such as synthesizers) can also be configured to produce different varieties of audio output.

FIG. **10** illustrates a process **1000** for concurrently processing multiple threads of bio/neurometric data using a common vocabulary derived from spectral analysis of a live audio input, in accordance with embodiments. As an example, the process **1000** may be used by the creative circuit system **800** shown in FIG. **8** and described herein, where the live audio input is a live performance by the second user **803**. The process **1000** may be carried out using one or more components of a creative circuit module, such as, e.g., the module **200** shown in FIG. **2**, and/or the module **808** of FIG. **8**, or using any computing device having corresponding software stored on a computer readable medium and executable by one or more computer processors. While FIG. **10** specifically shows concurrent processing of data streams obtained from two separate human subjects, it should be appreciated that the incoming data of three or more human subjects may be concurrently processed using similar techniques. In other embodiments, the process **1000** may be used to processing a single thread of B/N data using common vocabulary derived from spectral analysis of live audio input.

Generally, the process **1000** provides an exemplary algorithm for determining audio and video output based on input bio/neurometric data received from separate users, with commonality gained by use of a shared parameter file **1010** and vocabulary datastore **1011**. As shown, the process **1000** utilizes spectral analysis, and a resulting common datastore **1011**, to determine a musical output based on incoming EEG data from both human subjects, each in a separate processing thread, thus allowing concurrent thread execution and hence, merged concurrent audio and video output. In one embodiment, the multi-threading can be handled using the multi-threading capabilities built into the Python programming environment. As shown, although the threads run concurrently in FIG. **10**, they can share data, in this case the global parameter file **1010** and the common vocabulary datastore **1011**.

Portions of the process **1000** may be similar to the process **400** shown in FIG. **4**A. For example, the process **1000** may begin with a bio/neurometric data listener **1002**, similar to the B/N data listener **402**, providing the incoming data streams or threads from individual human subjects to a TCCS dispatcher **1004**, similar to the TCCS dispatcher **404**. The data listener **1002** may be configured to make multiple connections to different data collection devices (such as, e.g., the B/N data collection headsets **802** and **805** shown in FIG. **8**), and hence multiple human subjects (e.g., users **801** and **803** in FIG. **8**). The TCCS dispatcher **1004** may assign a respective one of a plurality of processing plug-ins ("PPI") **1006** and **1008** (similar to PPIs **406** and **408**) to each human subject, or otherwise provide each thread to the respective processing plug-in. In embodiments, each processing plug-in **1006**, **1008** may concurrently operate according to the process **420** shown in FIG. **4**B, thus enabling the process **1000** to concurrently process both data threads and produce separate outputs based thereon that are musically coherent.

In FIG. **10**, each plug-in **1006**, **1008** also receives parameters from the shared TCCS parameter file **1010**, which provides, for example, common pitch and/or rhythm data (or vocabulary) to be used for both threads. The TCCS parameter file **1010** may be substantially similar to the shared TCCS parameter file **410** shown in FIG. **4**A and described herein, except that the common vocabulary is determined based on data received from a TCCS spectral analyzer **1012**. Also, unlike the parameter file **410**, the parameter file **1010** does not include a vocabulary datastore. Instead, the vocabulary datastore **1011** is stored separately from the parameter file **1010**, as shown in FIG. **10**.

According to embodiments, the spectral analyzer **1012** can be configured to measure the amplitude or power of each frequency of an input signal and based thereon, determine various other spectral aspects of the signal, such as, e.g., power, harmonics, bandwidth, etc. In some embodiments, the output of the spectral analyzer **1012** may include a frequency component and a corresponding power component identified from the input signal. The spectral analyzer **1012** may be implemented in hardware, software, or any combination thereof.

In embodiments, the vocabulary datastore **1011** may contain a "real-time" vocabulary that is dynamically populated based on the results of the spectral analysis performed by the spectral analyzer **1012** on the user-provided content. In some embodiments, the vocabulary datastore **1011** may include a JSON file comprising JSON arrays, with each JSON object representing a note. For example, one JSON array for representing the pitch vocabulary may be: ["C#5", "F#4", "C#6", "B5", "E4", "G6", "A#5", "C6", "D6", "G4", "A2", "A4", "G#5"], which includes pitch values corresponding to the frequencies extracted from the user-provided content by the spectral analyzer **1012**, ordered by the intensity of volume level, or power, also extracted by the spectral analyzer **1012** for each frequency. In other embodiments, the real-time vocabulary may be provided as an array comprising pairs of pitch values (or the corresponding MIDI note numbers) and volume levels corresponding to the frequency and power components identified by the spectral analyzer **1012**. For example, the array may include 127 elements representing all possible MIDI pitch numbers, with each element containing a volume level in decibels.

As shown in FIG. **10**, the process **1000** further includes receiving a live audio input at an audio interface **1014**. As an example, the audio interface **1014** may be a software component residing in the creative circuit module **808** and configured to interface with, or receive live input data from, the audio input device **810** for capturing the live performance shown in FIG. **8**. The audio interface **1014** sends the received data to the TCCS spectral analyzer **1012**, which populates the vocabulary datastore **1011** with preferred pitches based on spectral information (or frequency components) extracted from the live audio input, thus creating a real-time common vocabulary for pitches. The spectral information may include, for example, frequencies and overtones detected or identified in the user-provided content. In some cases, the extracted information may also be analyzed for rhythm data and used to populate the rhythm vocabulary, for example, using the LibROSA beat module. In some embodiments, the parameter file **1010** may include a variable "recordEnable=True" that causes the creative circuit module to start recording the live audio input, the recorded files then being provided to the spectral analyzer **1012** for analysis.

In embodiments, based on its analysis of the incoming audio, the spectral analyzer **1012** may create an array representing overtones in the incoming audio stream, binned into MIDI pitch buckets. This array may be saved in the vocabulary datastore **1011** as the pitch vocabulary in a JSON file, for example, and may be dynamically populated or updated as the spectral analyzer **1012** continues to process the incoming audio. When the processing plug-ins **1006**, **1008** request pitch vocabulary from the parameter file **1010**, the array may be retrieved from the vocabulary datastore **1011** and provided to the processing plug-ins as the "preferredNotesArray" for deriving a musically coherent output from the incoming B/N data. In this manner, the frequencies and overtones detected in the user-provided content may be used as the preferred notes for translating the B/N data into musical tones.

In some embodiments, the pitch vocabulary array includes 127 elements representing all possible MIDI pitch levels or numbers, and each array entry may include the volume level detected in the incoming audio content for the frequency that matches, or most closely matches, the frequency of the corresponding pitch level. In other embodiments, the array may only include entries for preferred pitches. For example, an array created upon spectral analysis of input audio detected during the live performance shown in FIG. **8** may include a volume or power level of 93 for MIDI pitch number 24, a power level of 72 for MIDI pitch number 59, a power level of 12 for MIDI pitch number 79, and a power level of 6 for MIDI pitch number 127. In still other embodiments, the array may be a list of pitch values ranked by volume level, rather than explicitly including the power values. In such cases, the volume level for each pitch value may be implicitly represented in the ordering of the pitch values. The exact form used for the pitch vocabulary may be set using variables in the parameter file, for example, by setting the variable "volumeRepresentation" equal to "Summary" for the ordered pitch value representation, or "Detailed" for the array of volume levels representation.

Regardless of the exact form, such "pitch sets" or pitch vocabulary may be stored in the vocabulary datastore **1011** as the real-time pitch vocabulary, and may be used by appropriate plug-in selector functions of processing plug-ins **1006** and **1008** to choose pitch representation for incoming bio/neurometric data, for example, in accordance with the process **420** shown in FIG. **4**B. Thus, the vocabulary datastore **1011** can define the pitch vocabulary to be used in the algorithm that converts the EEG data to sound, thereby allowing the audio output created based on both subjects together to be musically coherent.

In embodiments, the calculation of which pitch and volume (or velocity) to render in the output may be done by the creative circuit module **808** (or TCCS Server Application) and may be transmitted to the audio engine **818** (e.g., Logic Pro or other DAW) using the MIDI protocol. The MIDI protocol also specifies a channel, allowing mapping to a specific instrument. For instance, channel 5 may be assigned to a cello. The choice of how to render video may be determined by the visual engine **820**, for example, using custom code in the Unity system. The data may be transmitted to the visual engine **820** via the OSC protocol, and a section of C# code may determine what video to render based on the shared parameter file **1010** and vocabulary datastore **1011**.

One example of a live performance that may be processed using the process **1000** is user spoken input (or a vocal performance), in which a single subject uses spoken word as the content to merge with the EEG data received via the data listener **1002**, to produce a hypnotically powerful artifact (or output) that can be used by the user to reinforce the media content of choice, or otherwise enhance a hypnotic suggestion.

For instance, the user may wear the EEG headset **802**, and read out loud, repeatedly, a phrase representing a target psychological state the person aspires to such as: "Every day I remember to be thankful for all I have been given." The process **1000** may be used to reinforce this hypnotic suggestion through the interplay of audio signals representing the user-provided content and biometric signals obtained from the EEG headset **802** while the user is reading this phrase. For example, the spectral analyzer **1012** may be used to extract phonetic content, as well as the primary pitch and overtones present in the audio stream representing the user's voice. This information may be converted into MIDI data representing overtones each with a corresponding volume (or velocity) level, or the real-time pitch vocabulary. The

MIDI data may then be used by an appropriate processing plug-in to derive pitch values for the incoming EEG data and produce an output array of volume levels at different frequencies. The resulting audio output may be a "soundscape," which may be more like a texture than a song, or a harmonic progression with multiple tones rendered as chords, or as an individual melody, with these options depending on the processing plug-in algorithm and additional characteristics, such as timbre and instrumentation settings, being controlled by the settings of the audio engine. A feedback loop is created when this output is heard by the user and influences the way they read the words in the next iteration, which in turn changes the next output, and so on. It has been shown that the mind can adjust itself to produce EEG patterns that the subject wants to reinforce. Thus, the feedback process described herein, where the user is aware of the inclusion of their content in the creative process, may create a powerful reinforcing mechanism capable of increasing the hypnotic suggestive effect.

In another example, one or more subjects could play musical instruments and repeat a song or improvise over a chord progression, using the feedback loop to enhance their interpretation of the music they are playing, or inspire creative ideas.

In another example, one or more subjects could use the techniques described herein to perform free-form improvisation of music or spoken word, continually evolving their own content in response to the system feedback, in what might be termed an improvisational call and response with their own merged content. In these examples, bio/neurometric data from the one person, or multiple persons, involved could be taken into account by the appropriate processing plug-in.

Another possibility for user-provided input could be in the form of user movement, picked up by a camera and sent to the system in a custom parameter, or the user could draw on a digital tablet, providing coordinate data or pressure or color choice data in real-time that can be taken in as a custom parameter and used in an appropriate processing plug-in.

In another configuration, the system(s) described herein could be used with pre-existing EEG files that are played back through the system in a loop (such as, e.g., the playback mode shown in FIG. **3** and described herein). With files of different lengths looping and going to different MIDI channels, the effect is a continuously varying audio and/or video stream, providing a musical and/or visual texture to be used for relaxation, entertainment, creative stimulation, guided meditation, or other beneficial purposes.

The system(s) described herein can be configured so that different EEG bands can be associated with different MIDI channels, and different users can be associated with different channel ranges. So, for instance, a subject could have their brain wave power in the Alpha range to be associated with a flute, while all other bands are used to determine output from a violin. Each subject can have their own customized choices of what brain wave is associated with what instrument or form of output.

The system(s) described herein can also be configured so that user-provided content is recorded in multiple segments, each generating its own output of audio characteristics, which the algorithm for pitch/rhythm/harmony selection cycles through iteratively, allowing for variety such as sections with different keys, chords, styles etc.

The system(s) described herein can be configured to support multiple individuals wearing headsets, each individually identifiable on separate ports in the system. In the event latency and performance becomes an issue, because the input data supports receiving EEG through Wide Area Network (WAN) transfer protocols such as UDP, the system can support daisy chaining of computer systems and aggregation of EEG data before transmission across a network. So, far-instance, to support 100 users one might use 10 computers, each computer handling 10 users, aggregating the EEG data, and sending only average and/or peak values to a central node. These techniques, plus other, known networking techniques, may be used to support the group examples described here.

FIG. **11** illustrates an exemplary process **1100** for selecting appropriate audio representations (such as, e.g., pitch and velocity, or volume, parameters) for received bio/neurometric data, using a parameter file and vocabulary datastore, in order to convert EEG data to sound, in accordance with embodiments. As an example, the process **1100** may be used by any of the creative circuit systems **100**, **500**, **600**, **700**, **800**, and/or **900**, or the creative circuit module included therein, to map received B/N data to appropriate pitch and velocity values. In particular, the process **1100** may be carried out using one or more components of the creative circuit module (e.g., the module **200** shown in FIG. **2** and/or the module **300** shown in FIG. **3**), such as, for example, a processing plug-in included therein, or using any computing device having corresponding software stored on a computer readable medium and executable by one or more computer processors. In the case of multiple input B/N streams from multiple users, the process **1100** may be concurrently carried out for each stream of B/N data (or each user) by the appropriate processing plug-in (e.g., as shown in FIG. **10**). The parameter file and/or vocabulary datastore may be substantially similar to at least one of the TCCS parameter file **410** shown in FIG. **4**B and the TCCS parameter file **1010** and vocabulary datastore **1011** shown in FIG. **10**, or otherwise use the techniques described herein with respect to vocabulary usage and parameter selection.

As described herein, the vocabulary may be either prepopulated (i.e. static) or dynamically populated based on analysis of input audio and/or visual data (e.g., from a live performance). In the case of static vocabulary, the vocabulary datastore information may be stored or held in the parameter file and represented by arrays of notes, for example. In the case of real-time vocabulary, the vocabulary datastore information may be stored or held in a separate file capable of being dynamically populated, such as, for example, a JSON file containing JSON arrays, with each JSON object representing a note. Which vocabulary datastore implementation is chosen can be based on system requirements, such as, e.g., performance and ease of access. In some embodiments, the vocabulary datastore may be implemented as a database, such as, e.g., relational, document-oriented, or other suitable database types.

The illustrated process **1100** provides one method for determining pitch and volume, or velocity, of a given note based on incoming EEG data. This logic might be included in the "EEGMuse2PitchSelector" algorithm described above with respect to FIG. **9**, for example. In one example, the power of a given brain wave frequency, provided in microvolts, may be detected in the Alpha range (e.g., 8-12 hertz (Hz)) and used as the basis for calculation. At step **1102**, the brain wave frequency value (or EEG power) may be scaled up to above a predetermined frequency threshold, for example, so that the value falls within the range of possible human-hearable frequencies (e.g., 20 Hz to 20 kHz), for example, by multiplying the value by a factor of 100 or other preset number. In this manner, a candidate pitch is chosen.

Next, the nearest MIDI note to the candidate pitch is located within the vocabulary datastore to determine the pitch value to include in the output. To create variety in the volume, a higher value may correspond to a louder volume. In particular, at step **1104**, the process **1100** determines whether the brain wave frequency is diatonic in (or involves the notes for) a key of D major or in a key of A major. This may be achieved, for example, by comparing the candidate pitch to the pitches which are diatonic in a given key. The process **1100** may also include, at step **1106**, obtaining appropriate vocabulary from a pitch vocabulary datastore. As shown, the vocabulary may include, for example, data fields indicating that a first tonal center corresponds to the key D major and a second tonal center corresponds to the key A major. The vocabulary obtained at step **1106** may determine which keys are sought in step **1104**, for example.

If the answer at step **1104** is no (i.e. the brain wave frequency (candidate pitch) is not diatonic in one of the desired keys), the process **1100** continues to step **1108**, where a nearby frequency candidate is calculated. The nearby frequency to the candidate pitch may be calculated, for instance, by rounding the candidate pitch up until it corresponds to a note that is a half-step higher. The calculated frequency candidate is then analyzed again at step **1104**. This loop may continue until the analysis at step **1104** results in a "Yes" answer, or until the analyzed frequency is diatonic in the key of D major or A major. Once that occurs, the process **1100** continues to step **1110**, as shown in FIG. **11**. At step **1110**, the frequency that is diatonic in either D major or A major is used as is, and converted to an appropriate MIDI note (or pitch) number using the standard mathematical function for converting a frequency (expressed in hertz) to a MIDI note value.

At step **1112**, the EEG power level of the brain wave may also be used to set the velocity or volume of the audio representation. For example, the MIDI velocity may be calculated for the brain wave frequency by using the MIDI pitch number (e.g., 0-127) as the velocity. This will make higher pitches louder and lower pitches softer. As another example, the velocity may be based on the ratio of Alpha strength to Beta strength in microvolts, so that the stronger Alpha is relative to Beta, the louder the signal. In some cases, the developer of the processing plug-in may implement different algorithms in an effort to find what mapping of brain waves to velocity creates the most effective creative circuit. The MIDI pitch or note number and the MIDI velocity number may be packaged in an output array and, at step **1114**, may be sent to an audio engine, such as, e.g., audio production module **118** of FIG. **1**, for generating an appropriate audio output based thereon. The audio output may be delivered to the user via an audio output device of the system, such as, e.g., audio output device **114** shown in FIG. **1**.

The above is just one example, as many other algorithms could be used. For instance, another possibility is one could perform a mapping using the amplitude of a sampled interval, and scaling that value up to determine pitch, while using the power in microvolts to determine velocity. So, for instance, 9 Hz might scale up to 440 Hz, which maps to MIDI note **120**(A), and the power of 0.8 microvolt (μV) might scale up to a velocity of 6. The techniques described herein are not limited to one particular algorithm, but allow for plugging in of different methods to suit the needs of a particular use case.

FIG. **12** illustrates an exemplary process **1200** for selecting appropriate visual representations (e.g., visual angle or ray, shape, and color parameters) for incoming bio/neurometric data using information retrieved from a parameter file and vocabulary datastore, in order to convert EEG data into images or other visual output, in accordance with embodiments. As an example, the process **1200** may be used by any of the creative circuit systems **100**, **500**, **600**, **700**, **800**, and/or **900**, or the creative circuit module included therein, to map received B/N data to appropriate color, shape, and angle values, or other visual representations. In particular, the process **1200** may be carried out using one or more components of the creative circuit module (e.g., the module **200** shown in FIG. **2** and/or the module **300** shown in FIG. **3**), such as, for example, a processing plug-in included therein, or using any computing device having corresponding software stored on a computer readable medium and executable by one or more computer processors. In the case of multiple input B/N streams from multiple users, the process **1200** may be concurrently carried out for each stream of B/N data (or each user) by the appropriate processing plug-in (e.g., as shown in FIG. **10**). The parameter file and/or vocabulary datastore may be substantially similar to at least one of the TCCS parameter file **410** shown in FIG. **4**B and the TCCS parameter file **1010** and vocabulary datastore **1011** shown in FIG. **10**, or otherwise use the techniques described herein with respect to vocabulary usage and parameter selection.

In general, the image selector process **1200** shown in FIG. **12** may be analogous to the functions performed by the pitch selector process **1100** for generating an audio output. For instance, the vocabulary datastore may contain a repository of allowed geometric symbols and colors, either pre-defined statically or gained through image analysis of incoming visual data. In the illustrated embodiment, for example, the list of shapes in the vocabulary datastore includes Circle, Triangle, and Cube; the range of colors in the vocabulary includes Magenta, Black, and Purple; and the range of angles includes 15 degrees, 20 degrees, and 45 degrees. The use of a parameter file allows one to specify, for a given configuration, how biometric/neurometric data should be mapped to the audio and visual domains.

In embodiments, the logic represented by process **1200** may be included in the "EEGMuse2ImageSelector" algorithm described above with respect to FIG. **9**, for example. As shown in FIG. **12**, the image selector process **1200** may begin at step **1202** with receipt of an incoming data item, such as, e.g., a brain wave frequency with power of 0.9 μV in the Alpha range. The brain wave frequency may be scaled up so that it falls within a valid MIDI velocity range (e.g., 0-127), or at least above a predetermined threshold. Use of the MIDI ranges here, even though not for an audio output, can allow for standardization of the numeric representations across both the audio and video engines and thus, help generate a coherent output from both.

Next, the parameter file and vocabulary datastore may be referenced in order to obtain appropriate image values for the input data. For example, at step **1204**, the parameter file may indicate that the Alpha range power data should be rendered as angles (or rays) and should be mapped to a specific shape and color based on the image vocabulary provided by the vocabulary datastore at step **1206**. In the illustrated embodiment, the vocabulary datastore placed the shapes and colors in arrays ordered by relative frequency of occurrence of those representations within the visual data extracted from the user-provided data (e.g., as shown in FIG. **13**), and the parameter file indicates that values in the Alpha frequency range should be mapped to array slot 1 for both the shape and color array, as shown in FIG. **12**. In other embodiments, the array slots may be ordered based on other factors, such as, for example, color parameters (e.g., hue, lightness/darkness level, saturation, etc.).

At step **1208**, a scaling function can be applied to the power level of the input data value, resulting in a value between for instance 0 and 360 degrees, and the nearest value in the angle vocabulary provided by the vocabulary datastore may be chosen. So, for instance, a scaled value of 16 for the input power level would result in rendering a 15 degree ray at step **1210**, as 16 is closer to 15 than 20. Thus, based on the rules provided in the exemplary process **1200**, where the shape array is [Circle, Triangle, Cube] and the color array is [Magenta, Black, Purple], for an input brain wave frequency have 0.9 μV of Alpha power, the "EEGMuse2ImageSelector" algorithm will output a rendering of a ray angled at 15 degrees and embedded in a magenta-colored circle. As will be appreciated, other outputs may be obtained using different image vocabulary and parameter files.

FIG. **13** illustrates an exemplary process **1300** for creating a feedback loop as a single user produces audio content while wearing an EEG headset and listens to an audio output generated based on the collected EEG data and captured audio content, in accordance with embodiments. The process **1300** may be carried out using a system that comprises a bio/neurometric data collecting headset to be worn by a user (such as, e.g., an EEG headset as shown in FIG. **13**), an audio input device (such as, e.g., a microphone) for detecting audio content representing a live performance of the user, a computing device (such as, e.g., a tablet or a laptop, desktop, or server computer) for creating a coherent, audio output based on the detected audio and the data collected by the headset, and one or more audio output devices (such as, e.g., audio speakers or a personal listening device) for presenting the audio output to the user. Portions of the process **1300** may be carried out by a creative circuit module (such as, e.g., the creative circuit module **200** shown in FIG. **2**) included in the computing device. In some embodiments, the process **1300** may be implemented using the creative circuit system **100** shown in FIG. **1** and/or the creative circuit system **600** shown in FIG. **6**.

As shown in FIG. **13**, the process **1300** may begin at step **1302** with detection of user-provided audio content, or audio generated by a live performance of the user, using the audio input device (e.g., audio input device **110** shown in FIG. **1**). The audio content may be a vocal performance, such as, e.g., spoken word or singing, or a musical performance, such as, e.g., playing an instrument (like the musical instrument **811** shown in FIG. **8**). The audio content may be provided to a computing device (such as, e.g., computing device **106** shown in FIG. **1**) for analysis by a creative circuit module included therein (such as, e.g., creative circuit module **108** shown in FIG. **1**).

At step **1304**, the module may identify one or more aspects of the input signal by, for example, extracting metadata from the user-provided content, such as, e.g., volume, pitch, etc., and may use these aspects to create a vocabulary. As an example, the creative circuit module may include an audio interface for receiving the detected audio content, a TCCS spectral analyzer for analyzing the incoming audio, a vocabulary datastore for creating new vocabulary based on the live input data, and a TCCS parameter file for setting the vocabulary and other parameters to be used by a processing plug-in for generating the output, as shown in steps **1014**, **1012**, **1011**, and **1010**, respectively, of FIG. **10**. In such cases, the spectral analysis techniques described herein with respect to FIG. **10** and otherwise may be used to extract volume, pitch, and other metadata from the user-provided content and deposit the extracted information into an array, thus creating the new vocabulary. The resulting vocabulary may be provided to a processing plug-in also included in the module (such as, e.g., PPI **206** shown in FIG. **2**).

At step **1306**, bio/neurometric data may be collected from the user, or more specifically, the EEG headset or other B/N data collection device worn by the user, and provided to the creative circuit module for analyzing the B/N data. It should be appreciated that in some cases, two or more of the steps **1302**, **1304**, and **1306** may occur simultaneously, or nearly simultaneously, while in other cases, certain steps may occur before others. The process **1300** is not limited to an exact order of these steps, so long as a feedback loop is created.

At step **1308**, the processing plug-in included in the creative circuit module creates a new audio output based on the metadata generated at step **1304** and the EEG data collected at step **1306**. For example, the processing plug-in may use all or portions of the process **1000** shown in FIG. **10** and/or the processes **400** and **420** shown in FIGS. **4**A and **4**B, respectively, in order to create the audio output. The audio output may be delivered to, or played for, the user through one or more audio output devices (such as, e.g., audio output device **114** shown in FIG. **1**). In this manner, the user is able hear sounds generated based on their own B/N data and live audio content, which may then influence the user's continued thought and content creation, thus creating a feedback loop.

FIG. **14** illustrates an exemplary creative circuit system **1400** configured to create a coherent output based on multiple inputs and use targeting logic to direct the output to an appropriate output generator, in accordance with embodiments. As shown, the creative circuit system **1400** comprises a computing device **1406** configured to receive various types of inputs, including bio/neurometric (B/N) data and user-provided content, and provide the received inputs to select components of a creative circuit module **1408** included in the device **1406** for processing the inputs. Certain components of system **1400** may be substantially similar to corresponding components of the creative circuit system **100** shown in FIG. **1** (or other systems described herein) and therefore, will not be described in detail here for the sake of brevity. For example, the computing device **1406** may be substantially similar to the computing device **106** shown in FIG. **1**, and the creative circuit module **1408** may be substantially similar to the module **108** shown in FIG. **1**, the module **200** shown in FIG. **2**, and/or the module **300** shown in FIG. **3**. In some cases, the process **1300** shown in FIG. **13** may be implemented using components of the system **1400**.

In embodiments, the creative circuit system **1400** includes a bio/neurometric data input system **1402** communicatively coupled to the computing device **1406** (e.g., via a wired or wireless connection) for providing live and/or pre-recorded bio/neurometric data to the creative circuit module **1408**. The B/N input system **1402** may include one or more B/N data collection devices configured to collect one or more types of B/N data, such as, e.g., EEG data, heart rate data, blood pressure data, galvanic skin response data, etc. In some embodiments, the B/N input system **1402** may include an EEG headset, such as, e.g., the Muse 2 headset, and/or other data collection device similar to the B/N data collector **102** shown in FIG. **1**. In some embodiments, the B/N input system **1402** may also include a data receiver communicatively coupled to the B/N data collection device and configured to convey B/N data received from the collection device to the computing device **1406**, for example, similar to the B/N data receiver **104** shown in FIG. **1**.

As shown in FIG. **14**, the B/N input system **1402** may be configured to transmit a live B/N data stream to the computing device **1406**, such as, for example, B/N data obtained in real-time from a user wearing an EEG headset or other B/N data collection device (e.g., as shown in FIG. **5**). The B/N input system **1402** may also be configured to provide pre-recorded B/N data files to the creative circuit module **1408**. For example, in some cases, the B/N data may have been previously collected by a B/N data collection device of the B/N input system **1402**. In other cases, the B/N data may have been obtained by the B/N input system **1402** from another source. In either case, the B/N data files may be stored in a memory of the B/N input system **1402** until requested by the computing device **1406**. In some embodiments, the B/N input system **1402** may include a file manager, similar to the file manager **312** shown in FIG. **3**, for storing the pre-recorded B/N data for future use.

As shown in FIG. **14**, the creative circuit system **1400** also includes an audio/visual input system **1409**, similar to the audio/visual input system **109** shown in FIG. **1**. In embodiments, the audio/visual input system **1409** can include at least one audio input device, such as, e.g., a microphone, for capturing live audio data or signals (e.g., similar to the audio input device **110** shown in FIG. **1**), and at least one video input device, such as, e.g., a camera, video recorder, or webcam, for capturing live images, video, or other visual data (e.g., similar to the video input device **112** shown in FIG. **1**).

As shown, the audio/visual system **1409** can be configured to transmit a live video stream, a live audio stream, pre-recorded audio data, and/or pre-recorded video data to the computing device **1406**. In some embodiments, the audio/visual system **1409** may transmit other types of non-live data to the computing device **1406** that is not necessarily pre-recorded, such as, e.g., an audio track or video file generated by a computer and transmitted directly to the computing device **1406**, etc. The live streams may include audio and/or video data captured by the audio/visual system **1409** and transmitted to the computing device **1406** in real-time. In some cases, the pre-recorded data may have been previously collected by the audio and/or video input devices of the system **1409**. In other cases, the pre-recorded audio and/or video data may have been obtained by the audio/visual input system **1409** from another source (e.g., downloaded). In either case, the non-live audio and/or video data may be stored in a memory of the audio/visual input system **1409** until requested by the computing device **1406**.

The creative circuit module **1408** comprises various components for receiving and processing the incoming data, whether live, pre-recorded, or otherwise, including a spectral analysis module **1430** for analyzing all incoming audio data and an image analysis module **1432** for analyzing all incoming video data. The spectral analysis module **1430** may be configured to extract metadata (e.g., pitch, volume, etc.) from the incoming audio data, or otherwise identify aspects of said data, and create an appropriate audio vocabulary based thereon, for example, similar to the TCCS spectral analyzer **1012** shown in FIG. **10** and described herein. The image analysis module **1432** may apply similar to techniques for extracting metadata (e.g., shape, color, angle, etc.) from the video data and creating an image vocabulary based thereon.

As shown in FIG. **14**, each of the modules **1430** and **1432** may be configured to provide the newly acquired vocabulary to a vocabulary datastore **1434** of the creative circuit module **1408**. As such, the vocabulary datastore **1434** may be dynamically populated with a common vocabulary that can be applied to all incoming B/N data to create a coherent output based thereon. In some embodiments, the vocabulary datastore **1434** may be similar to the vocabulary datastore **1011** shown in FIG. **10** and may include, for example, a pitch vocabulary datastore as shown in FIG. **11** and a shape vocabulary datastore as shown in FIG. **12**. The creative circuit module **1408** also includes one or more TCCS parameter files **1436** configured to store parameter information and threshold information for use during output generation, for example, similar to the TCCS parameter file **1010** shown in FIG. **10**. The parameter file **1436** may include a set of instructions for applying the common vocabulary to the incoming data, for example, as shown in FIG. **12**.

The creative circuit module **1408** further includes a selection module **1438** configured to receive all B/N data, live or pre-recorded, from the B/N input system **1402**, parameter information from the TCCS parameter file **1436**, and vocabulary information from the vocabulary datastore **1434**. Based on the received information, the selection module **1438** may create an output array comprising a plurality of data field (e.g., pitch, volume, image) and a value selected for each field. The data fields may be set or determined by the parameter file. The values for each data field may be selected by the module **1438** using one or more algorithms for mapping the received B/N data to the common vocabulary received from the vocabulary datastore **1434**. The algorithm(s) may be stored in the module **1438** and may be similar to, for example, the processes **1100** and **1200** shown in FIGS. **11** and **12**, respectively. In some embodiments, the selection module **1438** may be implemented as a processing plug-in, such as, e.g., PPI **206** shown in FIG. **2**, and may be configured to carry out the process **420** shown in FIG. 4B.

As shown in FIG. **14**, the creative circuit module **1408** further includes a targeting module **1440** configured to receive the output array from the selection module **1438** and determine which output generation engine may be best suited for generating an audio/visual output based on the received output array. In embodiments, the targeting module **1440** may be called or utilized only if a predetermined threshold is hit for an input data sample, wherein the threshold is provided by the parameter file **1436**. The targeting module **1440** may include one or more algorithms for carrying out these and other operations and may be implemented as a plug-in, in some embodiments.

The output generation engines may include, for example, an audio engine **1418** that is substantially similar to the audio production module **118** shown in FIG. **1**, an audio/visual engine **1419** that is substantially similar to the audio/visual engine **619** shown in FIG. **6**, and a visual engine **1420** that is substantially similar to the graphics/animation engine **120** shown in FIG. **1**. Other output generation engines may also be included to accommodate other types of output generation techniques, as will be appreciated. In some embodiments, the engines **1418**, **1419**, and **1420** may be included in the computing device **1406** and in communication with the creative circuit module **1408**, as shown in FIG. **14**. In other embodiments, the engines **1418**, **1419**, and **1420** may be included within the creative circuit module **1408**, itself.

The visual engine **1420** may be configured to provide a visual output (e.g., images, videos, or other visuals) generated based on the output array received from the targeting module **1440**, to a visual output device **1416** for delivering the visual output to the user, similar to the visual output device **116** shown in FIG. **1**. Likewise, the audio engine **1418** may be configured to provide an audio output (e.g., music, voice, or other sounds) generated based on the output array received from the targeting module **1440**, to an audio output device **1414** for delivering the audio output to the user, similar to the audio output device **114** shown in FIG. **1**. And the audio/visual engine **1419** may be configured to provide outputs generated based on the output array received from the targeting module **1440** to both devices, namely an audio output to the audio output device **1414** and a visual output to the visual output device **1416**. In some embodiments, the visual output device **1416** and the audio output device **1414** may be external devices (e.g., an external monitor and an external audio system) communicatively coupled to the computing device **1406**, as shown in FIG. **14**. In other embodiments, one or more of the visual output device **1416** and the audio output device **1414** may be integrated into the computing device **1406** (e.g., a native speaker or display screen).

Further details on the use of a parameter file to specify which plug-ins and audio/visual engines to use during operation of the system **1400** is provided in FIG. **15**, which depicts a table **1500** listing the name of exemplary TCCS parameters, a description of each, and an explanation of how each parameter is used in audio outputs and video outputs. In table **1500**, the given TCCS parameter may be used in the audio output to influence data values passed to the sound generation system, for example, via MIDI, OSC, or other audio streaming protocols, and may be used in the video output to influence data values passed to the visual generation system, for example, via OSC or other streaming data protocols. An exemplary parameter file **1800** is shown in FIG. **18**.

In traditional neurofeedback applications, targets or thresholds are defined for various neurometric data which produce new visual or audio stimuli if hit. The system **1400** supports this through the use of the targeting module **1440**, or a targeting plug-in, which can be inserted into the flow and can be customized for different use cases. Due to the support for multiple threads, multiple input types, and multiple users, the system **1400** is able to define heterogeneous group targets. So, for instance, the targeting plug-in **1440** can be written to specify that if the group average for power in the Alpha range is over 0.8 microvolts (wherein this threshold is specified in the parameter file **1436**), then send output MIDI to a second, different MIDI channel (which is also specified in the parameter file **1436**). For example, the second MIDI channel may be ringing a bell, whereas the first MIDI channel may be playing a violin, piano, or other instrument. The conditions under which the threshold is considered met could take into account multiple types of bio/neurometric data input, as well as audio input.

In some embodiments, one or more aspects of the system **1400** may be controlled by a human attendant **1442** to allow for real-time modification of parameters or settings according to the needs of a given use case. In such embodiments, the system **1400** may be further configured to receive an input from the attendant **1442** and adjust one or more settings based on the input. For example, the attendant **1442** may change the instrument that is assigned to a given MIDI channel (e.g., from bell to organ) upon listening to an audio output provided to one or more users or observing the reaction of a user.

As shown in FIG. **14**, the computing device **1406** may include a user interface **1444** for enabling the attendant **1442** to interact with the creative circuit module **1408**. For example, the user interface **1444** may be configured to receive inputs from the attendant **1442** and provide those inputs to the module **1408**. The user interface **1444** may be in communication with a processor of the computing device **1406** (such as, e.g., processor **124** shown in FIG. **1**) and may be implemented in hardware, software, or a combination thereof. For example, the user interface **1444** may be implemented as a console or electronic control panel comprising one or more input devices (e.g., keyboard, button, slider, dial, joystick, mouse, touchscreen, microphone, etc.) for receiving the attendant's inputs, and one or more software programs, executed by the processor, for interacting, and exchanging data, with the creative circuit module **1408**. The user interface **1444** may also include one or more output devices (e.g., display screen, speakers or other audio output device, etc.) for experiencing the outputs provided to the user, for observing the reactions of the user, and/or for viewing configurable settings of the creative circuit module **1408**.

In some embodiments, the creative circuit module **1408** may analyze a received input to determine which of its component(s) require modification and may send the input to the appropriate component. In other embodiments, the user interface **1442** may include separate interfaces (or consoles) for manipulating each of the targeting plug-in **1440**, the selection module (or processing plug-in) **1438**, the audio engine **1418**, the video engine **1420**, and the audio/visual engine **1419**, so that the received input can be directly routed to the appropriate component.

In embodiments, the system **1400** may be configured for various different modes of operation. The following paragraphs describe nine exemplary modes of operation. It should be appreciated, however, that other modes of operation are also contemplated in accordance with the teachings herein. Each of the nine modes is described below with examples. The modes labeled "Assisted" require participation of the human operator or attendant **1442**, referred to as a "Circuit Moderator" (CM), and require that the individual have access to the user interface **1444** capable of manipulating parameters available in each subsystem, referred to as a "Console." While the below discussion assumes existence of a targeting plug-in console, a processing plug-in console, an audio engine console, and a video engine console, other embodiments may include one console for controlling all components of the creative circuit module **1408**.

Mode 1: Real-Time, Unassisted, Untargeted Operation and Mode 2: Real-Time, Unassisted, Targeted Operation

In either of these modes, the user or users wear the headset or other biometric data capturing equipment, and the data is streamed in real-time from the biometric data source(s) to the Theta-u Creative Circuit System (TCCS), such as, e.g., the creative circuit system **1400** shown in FIG. **14**.

Starting State: Before the data flow starts, the TCCS system must be started, initialized with values and algorithms as specified in the TCCS parameter file, and the Audio and Video engines specified in the TCCS parameter file must be running, waiting for input and also set up with desired parameters and configurations.

Processing: The Processing Plug-in indicated in the TCCS parameter file is called for each sample received in real-time. The output values are streamed in real-time to the Audio and Video Engines specified in the parameter file. Each engine renders appropriate audio and video output based on the real-time data. In addition to applying the algorithms listed above as described for each TCCS parameter, in Targeted Mode, the system will check to see if rules described in the Threshold file are met, and if so, will render appropriate output. In Untargeted mode, no changes are made to the output data programmatically.

Examples of Usage:

Unassisted, Untargeted Operation (or Mode 1): A user enjoys cello-piano-flute combination, so Audio engine is setup with 3 tracks, each of which will receive data over MIDI channel 1. The system is launched with Processing-PlugIn-1 as described above, and the user hears output in real-time. The music evolves over the 10 minutes as the user adjusts to which thought patterns produce which result, and becomes able to modify the output to become more and more pleasurable as the brain adjusts to patterns which produce satisfying musical output.

Unassisted, Targeted Operation (or Mode 2): As in example above, a cello-piano-flute combination is setup, and the system is launched with ProcessingPlugIn-1. In addition, a threshold file is created which indicates that every time the average power in the Alpha range is above 0.05 microvolts (μV) for over 500 milliseconds (ms) in the octave, the pitch representing Alpha power will be raised one octave. Also, this value will be sent over MIDI channel 2, a channel reserved for targeted data, allowing the audio engine to treat this data with specific instrumentation. This example shows that the TCCS system can be used to create a neurofeedback system usable by therapists, similar to systems such as the @Nexus system.

Mode 3: Real-Time, Assisted, Untargeted Operation and Mode 4: Real-Time, Assisted, Targeted Operation

In either of these modes, the user or users wear the headset or other biometric data capturing equipment, and the data is streamed in real-time from the biometric data source(s) to the ThetaU Creative Circuit System (TCCS), such as, e.g., the creative circuit system **1400** shown in FIG. **14**.

Starting State: Before the data flow starts, the TCCS system must be started, initialized with values and algorithms as specified in the TCCS parameter file, and the Audio and Video engines specified in the TCCS parameter file must be running, waiting for input and also setup with desired parameters and configurations. A human attendant, i.e. the Circuit Moderator (CM), is watching and potentially making changes through one or more of the control consoles of the TCCS, such as, e.g., Processing PlugIn Console, Targeting PlugIn Console, Audio Engine Console, and Video Engine Console.

Processing: The Processing Plugin indicated in the TCCS parameter file is called for each sample received in real-time. The output values are streamed in real-time to the Audio and Video Engines specified in the parameter file. Each engine renders appropriate audio and video output based on real-time data. In addition to applying the algorithms listed above as described for each TCCS parameter, in Targeted Mode, the system will check to see if rules described in Threshold file are met, and if so, will render appropriate output. In Untargeted mode, no changes are made to the output data programmatically. As system processing proceeds, the CM may modify parameters of any of the components, including changing values in the TCCS parameter file, changing instrumentation in the Audio Engine, changing parameters such as field of view or zoom level or animation speed in the Video Engine, or changing values in the Targeting file. All of these changes will take effect in real-time.

Examples of Usage:

Assisted, Untargeted Operation (Mode 3): A user enjoys cello-piano-flute combination, so Audio engine is setup with three tracks. CM starts session with only cello track active and uses an iterative loop approach with audio engine to provide all three tracks. For example, after three minutes of cello only, which is being recorded in real-time, CM introduces piano with "backing track" of initial cello, allowing user's brain to create a piano track adjusting to input stimuli of initial cello track. CM records this piano track for three minutes. CM then plays back cello-piano track to user while introducing flute track and records flute as it responds to brain signals for three minutes. At this point, the user's brain has recorded all three instruments individually, creating a three minute cello-piano-flute composition, which the user has experienced hearing as it was incrementally created. At this point, the CM turns on recording for all three tracks simultaneously and records for three more minutes as the user's brain, consciously or unconsciously, adjusts to the input to achieve a desired audio result. The CM then stops the system, having facilitated the creation of a six minute composition produced by the user's mind.

Assisted, Targeted Operation (Mode 4): A user enjoys cello-piano-flute combination, so Audio engine is setup with three tracks, all of which will receive data over MIDI channel 1. The system is launched with selected ProcessingPlugIn and user hears output in real-time. In addition, initially a threshold file is created which indicates that every time the average power in the Alpha range is above 0.05 μV for over 500 ms in the octave, the pitch representing Alpha power will be raised one octave. Also, this value will be sent over MIDI channel 2, allowing the audio engine to treat this data with specific instrumentation. The CM adjusts the Audio Engine to place the flute track on channel 2, so it becomes the reinforcing instrument for this Alpha threshold. After three minutes, the CM introduces another threshold, indicating that every time the Beta range is below 0.07 μV for over 500 ms, the pitch representing Beta power will be lowered one octave. Also, this value will be sent over MIDI channel 3, allowing the audio engine to treat this data with specific instrumentation. The CM adjusts the Audio Engine to place the piano track on channel 3, so it becomes the reinforcing instrument for this Beta threshold. After observing the user's response for three minutes via the TCCS console, the CM notices difficulty achieving the Beta response, and changes the threshold target to target below 0.09 μV rather than 0.07 μV.

Mode 5: Playback, Unassisted, Untargeted Operation and Mode 6: Playback, Unassisted, Targeted Operation

In either of these modes, a human file containing biometric data from a session where the user or users wore a headset and/or other biometric data capturing equipment, and the data was recorded, is opened and processed by the ThetaU Creative Circuit System (TCCS), such as, e.g., creative circuit system **1400** shown in FIG. **14**.

Starting State: Before the data flow starts, the TCCS system must be started, initialized with values and algorithms as specified in the TCCS parameter file, and the Audio and Video engines specified in the TCCS parameter file must be running, waiting for input and also setup with desired parameters and configurations.

Processing: The Processing Plugin indicated in the TCCS parameter file is called for each sample found in the input file set. The output values are streamed to the Audio and Video Engines specified in the parameter file. Each engine renders appropriate audio and video output based on incoming data. In addition to applying the algorithms listed above as described for each TCCS parameter, in Targeted Mode, the system will check to see if rules described in Threshold file are met, and if so, will render appropriate output. In Untargeted mode, no changes are made to the output data programmatically. In playback mode, the targeting is obviously not going to have an effect on the input since it was pre-recorded; however, in this mode, it serves to introduce variety and possibilities for audio and visual highlighting of periods of the pre-recorded session where the brain was in a certain state.

Examples of Usage:

Unassisted, Untargeted Operation (Mode 5): A user enjoys cello-piano-flute combination, so Audio engine is setup with three tracks, each of which will receive data over MIDI channel 1. The system is launched with Processing-PlugIn-1 as described above, and the pre-recorded data is read in, processed, and streamed to the audio and video engines. The audio and video output is recorded, resulting in a composition sourced by the biometric data.

Unassisted, Targeted Operation (Mode 6): As in example above, a cello-piano-flute combination is setup, and the system is launched with ProcessingPlugIn-1. In addition, a threshold file is created which indicates that every time the average power in the Alpha range is above 0.05 μV for over 500 ms in the octave, the pitch representing Alpha power will be raised one octave. Also, this value will be sent over MIDI channel 2, a channel reserved for targeted data, allowing the audio engine to treat this data with specific instrumentation. This results in a composition with a new source of variety compared to the untargeted example, where the brain state of higher Alpha is highlighted through instrumentation and the higher octave.

Mode 7: Playback, Assisted, Untargeted Operation and Mode 8: Playback, Assisted, Targeted Operation

In either of these modes, a pre-recorded file containing biometric data from a session where the user or users wore a headset and/or other biometric data capturing equipment, and the data was recorded, is opened and processed by the ThetaU Creative Circuit System (TCCS), such as, e.g., the creative circuit system **1400** shown in FIG. **14**.

Starting State: Before the data flow starts, the TCCS system must be started, initialized with values and algorithms as specified in the TCCS parameter file, and the Audio and Video engines specified in the TCCS parameter file must be running, waiting for input, and also setup with desired parameters and configurations. A human attendant, i.e. the Circuit Moderator (CM), is watching and potentially making changes through one or more of the control consoles of the TCCS, such as, e.g., a Processing PlugIn Console, Targeting PlugIn Console, Audio Engine Console, and Video Engine Console.

Processing: The Processing Plugin indicated in the TCCS parameter file is called for each sample found in the input file set. The output values are streamed to the Audio and Video Engines specified in the parameter file. Each engine renders appropriate audio and video output based on incoming data. In addition to applying the algorithms listed above as described for each TCCS parameter, in Targeted Mode, the system will check to see if rules described in Threshold file are met, and if so, will render appropriate output. In Untargeted mode, no changes are made to the output data programmatically. As system processing proceeds, the CM may modify parameters of any of the components, including changing values in the TCCS parameter file, changing instrumentation in the Audio Engine, changing parameters such as field of view or zoom level or animation speed in the Video Engine, or changing values in the Targeting file. All of these changes will take effect in real-time.

Examples of Usage:

Assisted, Untargeted Operation (Mode 7): A user enjoys cello-piano-flute combination, so Audio engine is setup with three tracks. CM starts session with only cello track active and uses an iterative loop approach with audio engine to introduce the remaining tracks. After three minutes of cello only, which is being recorded in real-time, CM introduces piano with "backing track" of initial cello, allowing creation of a piano track. CM records this piano track for three minutes. CM then plays back cello-piano track while introducing flute track and records flute as it responds to incoming signals for three minutes. At this point the user's brain has recorded all three instruments individually, creating a three minute cello-piano-flute composition. At this point, the CM turns on recording for all three tracks simultaneously and records for three more minutes. The CM then stops the system, having facilitated the creation of a six minute composition with various segments of the input file overlaid against one another.

Assisted, Targeted Operation (Mode 8): A user enjoys cello-piano-flute combination, so Audio engine is setup with three tracks, each of which will receive data over MIDI channel 1. The user is also interested in highlighting their periods of high relaxation. After doing a dry run in unassisted mode and observing the average brain wave activity via the TCCS console, the CM creates a threshold file which indicates that every time the average power in the Alpha range is above 0.05 μV for over 500 ms in the octave, the pitch representing Alpha power will be raised one octave. Also, this value will be sent over MIDI channel 2, allowing the audio engine to treat this data with specific instrumentation. The CM adjusts the Audio Engine to place the flute track on channel 2, so it becomes the reinforcing instrument for this Alpha threshold. The CM runs the system with this threshold file in place and then changes the instrumentation by moving the piano to track 2, so both flute and piano react to the periods where the Alpha was higher. The CM, perhaps listening along with the patient, decides that this is the best instrumentation mapping and runs the system while recording the output, to have a completed composition to give to the user as an MP3 file.

Mode 9: Playback, Post-Processing Operation

In this mode, the biometric data from a recorded session can be processed in multiple passes, running the TCCS repeatedly with different parameter settings. For instance, in one run, note length might be set to 8, key to the key of D, and Tonal center to D. This will generate a set of MIDI files that can be imported into Logic Pro, or other Audio Engine, and laid against one another, and also a set of 3D model files that can be imported into Unity, or other Visual Engine. The 3D models are created using functions similar to those described for audio, with the output of each run of the processing plugin being a vertex or face, for example, as described in the OBJ file format developed by Wavefront Technologies. The resulting OBJ files can be imported into Unity. In another run, note length might be set to 4, key to the key of D, and tonal center to E, creating a Dorian Mode effect. All of the resulting MIDI and OBJ files can be used in combination. Also, this mode can be combined with any of the other modes above. For instance, a run could be done which generates OBJ and MIDI files; Logic Pro and Unity could be pre-loaded with these artifacts, creating a Unity Scene background; and then a playback, unassisted, targeted run (i.e. mode 6) could occur that animates this scene and overlays audio to the existing MIDI.

Note that in all modes of operation, interaction with musicians playing standard instruments is possible, whereby ensembles are reacting to the music produced by these instruments, which changes the brain output, which is heard by those musicians and which they can respond to, forming a creative circuit in this manner. Creative circuits can also be formed by a player with his own rendered brain output, by a player with the rendered output of others, including audience members, or by a player with others around him who are producing auditory or visual stimulation.

FIGS. **17**A and **17**B depict a table **1700** summarizing several possible examples of how a given creative circuit system (such as, e.g., the system **100** shown in FIG. **1**) can be setup and used, in accordance with embodiments. It should be appreciated that the table **1700** does not provide an exhaustive list of uses and that other uses are also contemplated. Also, while the examples provided in table **1700** use EEG data, all examples could be setup with other biometric data input such as, e.g., heart rate, blood pressure or galvanic skin response, using techniques described herein.

Thus, the techniques described herein include a system capable of creating and using a static or dynamically changing "vocabulary," predefined or generated in real-time, from live input and/or existing audio sources, as a common base to enable merging of bio/neurometric data from multiple people or sources (including previously generated brain wave or other bio/neurometric data files or data from animals) and generating a collaborative output that provides a coherent audio and/or visual result based on this common vocabulary. Possible use cases for such a system include, for example, a compositional system (where original music is composed from bio/neurometric data source); a live performance allowing the combination of live instruments, prerecorded sources, and bio/neurometric data; therapeutic applications where, for instance, teams in a business setting learn about collaboration through creating a composition together, with each providing different brain wave contributions to the whole, which is used as a metaphor for working out roles and functions within the group; and "humanization" of computer generated audio to add variety for performers using such audio to accompany themselves.

As further explained, the concepts of the above-described invention may be modified and adapted to apply to all of the five human senses. FIG. **19** provides a schematic overview of a system **1900** that can generate input from bio/neurometric data merged with user provided content. Bio/Neurometric data collector **1901** (or B/N data collector), such as, for example a neuroheadset from Muse Corporation, sends brainwave data to a bio/neurometric data receiver **1902** (or B/N data receiver), such as, for example, an application running on an Android or IOS device. This data is routed to a computing device **1907** executing creative circuit module **1908**. Additionally, data from audio input device **1903**, visual input device **1904**, smell/taste input source or device **1905**, and tactile input source or device **1906** are optionally routed to the computing device **1907** for use by the creative circuit module **1908**.

The creative circuit module uses processor **1910** of the computing device **1907** to execute algorithms selected from memory **1909**, also included in computing device **1907**, in conjunction with a parameter file to determine appropriate output for each of the senses (sight, sound, taste, smell, touch) and sends data to the appropriate production module (e.g., as shown in FIG. **24**). Graphics generation data goes to the graphics/animator engine **1911**, audio generation data goes to the audio production module **1912**, smell and taste data goes to the scent/flavor production module **1913**, and tactile data goes to the tactile production module **1914**. These modules, in turn, direct output to devices that can present to the user(s), namely, visual output device **1915**, audio output device **1916**, smell/taste output device **1917**, and tactile output device **1918**.

FIG. **20** illustrates an exemplary creative circuit module **1908** comprising various software components for implementing processing of incoming bio/neurometric data and a source material **2001**, which could be any liquid, solid, or gas, that is provided as an input to a material analysis device **2002**. A material analysis device is any device that can determine the chemical composition of a liquid, solid, or gas. One example would be a gas chromatography device that does comprehensive two-dimensional gas chromatography with software interfaces, for example, as described at https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7644112/, and produced by companies such as Agilent Technologies, such as the gas chromatography device described at https://www.agilent.com/en/product/gas-chromatography. Gas chromatography can be combined with mass spectrometry for a more accurate analysis. The process begins by loading an input compartment of the material analysis device **2002** with the substance or source material **2001** being analyzed, such as, for example a commercially available vegetable smoothie mixture. The material analysis device **2002** produces a digital list of the chemicals, elements, and/or compounds that are contained in the source material **2001**, which is stored in memory **1909** and available to creative circuit module **1908**. In a later step, this list can be provided as an input to the creative circuit module **1908**.

This is not necessarily a real-time process, as gas chromatography/mass spectrometry takes time on the order of minutes or hours rather than milliseconds or seconds in current implementations, although it could become real-time as the technology improves. The list may take the form of an array containing the names of the elements or compounds isolated by the analysis process and their percentages within the input source, for example sodium 5%. The output can also be subjectively post-processed by a human or automated process into higher level categories of scent or flavor, for example sweet 10%, indicating 10% of the input source contains elements or compounds that fall in the sweet category.

FIG. **21** provides a schematic overview of the flow to support the production of a scent or flavor. The scent/flavor production module **1913** is a software component that is capable of acting as a controller of one or more smart scent/flavor output devices **1917**. The scent/flavor production module **1913** receives instructions for operation via data messages from the creative circuit module **1908** (as also shown in FIG. **19**). These messages instruct the scent/flavor production module **1913** to send the appropriate commands to a particular scent/flavor output device **1917** to output a specific flavor (such as the flavor for beverage **2101**) or scent (such as the scent for aroma **2102**). An example of a scent/flavor output device is the Bartendro drink machine with software control, as described at https://partyrobotics.com/collections/products.

FIG. **21** shows a scent/flavor production module **1913** that is software module capable of sending command and control data to scent/flavor output device **1917** over a wired or wireless interface. The n number of storage compartments (**2105**, **2106** . . . **210***n*) in the scent/flavor output device **1917** can be pre-loaded with substances that were manually or automatically chosen through the process described in association with FIG. **20**. In particular, scent/flavor production module **1913** may be configured to generate a control sequence and provide it to scent/flavor output device **1917**. The control sequence may instruct scent/flavor output device **1917** to emit a specific amount of the substance in a given storage compartment. The protocol used by each scent/flavor output device **1917** may be specific to the manufacturer of that scent/flavor output device **1917**; thus, the scent/flavor production module **1913** may be manufacturer-specific as well. For instance, a manufacturer of a "Smart" drink-making device (a type of scent/flavor output device **1917**) may require that commands be sent in a specific j son data format over a Bluetooth connection with a protocol defining what json element names are used for each operation. For instance, sending {["Release", 2106, 100]} could be a command sent from scent/flavor production module **1913** to the scent/flavor output device **1917** telling it to release 100% of the contents in compartment **2106** into blending compartment **2199**. After sending a set of commands that load blending compartment **2199** from one or more storage compartments **2105**, **2106**, and/or **210***n*, scent/flavor production module **1913** may instruct the scent/flavor output device **1917** through another command sequence to distribute the blended result as an output such as, for example, beverage **2101** or aroma **2102**.

Data contained in the parameter file used by the creative circuit module **1908** (see FIG. **20**) indicates what substance is present in each compartment of scent/flavor output device **1917**. Hence, combining the processes defined in FIGS. **19-21**, an example could be as follows: An off the shelf beverage such as a vegetable smoothie could be analyzed as in FIG. **20**, and a list of ingredients and percentages could be generated. This list could be post-processed by human or automated means to produce a file containing representative output percentages of various taste categories, for instance {[{Bitter, 10%}, {Sweet, 5%}, {Salty, 2%}]. Storage compartments **2105**, **2106** and **201***n* in scent/flavor output device **1917** (FIG. **21**) could be loaded with bitter, sweet and salty substances, respectively. The vocabulary in this case is therefore [bitter, sweet, salty]. The creative circuit module **1908** could be configured to drive the scent/flavor production module **1913** based thereon, thereby producing drinks with varying percentages of bitterness, sweetness and saltiness, with variation driven by parameters defined in a parameter file and algorithms defined in a processing plug-in (e.g., as shown in FIG. **24**).

Different scent/flavor output devices will have different capabilities, and might be entirely different in function. For instance one could be a smart aromatherapy delivery device with the capability to deliver six different aromas while another could be a smart beverage making device with the capability to deliver a beverage based on the combination of liquids in ten different storage compartments. This is accommodated by the given architecture of a particular embodiment of the invention. So the parameter file could contain a variable scent/flavor output device-type. For scent/flavor output device-type="DrinkMaker1," the AlphaFlavorScentMultiplier parameter could define the influence of the Alpha wave EEG power over the amount of the liquid in storage container **210***n* that will be included in an output beverage. For scent/flavor output device-type="AromaTherapy1," the AlphaFlavorScentMultiplier parameter could define the influence of the Alpha wave EEG power over the amount of scent in storage container **210***n* (for example) that is used in an output aroma. In both cases creative circuit module **1908** would send a message to scent/flavor production module **1913** (with the logic to send this command implemented in a processing plug-in, as previously described), and the scent/flavor production module **1913** would send the appropriate control command to the scent/flavor output device **1917** for that particular device.

Regarding the protocol used to communicate from the scent/flavor production module **1913** to a scent/flavor output device **1917**, an example of an appropriate protocol to implement for message passing is Open Sound Control (OSC), described previously and also proposed for use in communicating between the visual output production module (or graphics/animator engine **1911**) and the visual output device **1915**, as shown in FIG. **19**. As described earlier, although the name OSC implies a reference to sound in particular, this protocol is designed to allow for a user-defined message set, which can have nothing to do with sound, as in this case. So for instance, a message can be passed from creative circuit module **1908** to the scent/flavor production module **1913** such as ["Release", 1, 0.5], which will indicate that 0.5 of the contents of storage compartment 1 (or compartment **2105** in FIG. **21**) should be released. The scent/flavor production module **1913** will interpret this appropriately based on the type of scent/flavor output device **1917** it is controlling. The communication between scent/flavor production module **1913** and scent/flavor output device **1917** will be manufacturer-specific and may or may not use a standard such as OSC (although, for convenience, that usage is shown as OSC herein).

As further shown in FIG. **21**, the system **1900** can also receive input from a human subject, such as bio/neurometric data generated by a subject **2165**, and use it in combination with the components needed to generate a scent or flavor based on the combination of the bio/neurometric data and previous analysis of a given input source material **2001**, or materials. The source material **2001** may be chosen based on input, such as foods, drinks, and/or scents the human subject **2165**, or subjects, have expressed a liking for. As described in association with FIG. **20**, the material analysis device **2002** analyzes each substance or source material **2001** and produces a list of chemicals, elements, and/or compounds that make up the source material(s) **2001**. This information is stored in memory **1909**. The storage compartments **2105** to **210***n* (indicating some variable "n" quantity) of the scent/flavor output device **1917** are loaded with chemicals, elements, and/or compounds that are going to make up the output scent or flavor based on this analysis. One possible flow is as follows: Human subject **2165** wears a neuro headset **2160** (such as a MUSE headset) as well as a heart rate or heart rate variability (HRV) monitor **2155** with wireless capability (such as a Fitbit or Apple watch). Data from these devices is transmitted over Bluetooth or other network protocol through the bio/neurometric data collector **1901** to the bio/neurometric data receiver **1902** (as shown in FIG. **19**) and then to the creative circuit module **1908** within computing device **1907** via wireless connection **2150**. Creative circuit module **1908** will use this data in conjunction with a parameter file stored in memory **1909** to determine a set of output values to send to scent/flavor production module **1913**.

One way of having bio/neurometric data influence the scent/flavor output is to have the percent of each material in the compartments of the scent/flavor output device **1917** used to output a final scent or flavor be determined partially or completely by the bio/neurometric data. The parameter file is used to determine how the bio/neurometric data will affect the output values. For instance, in a particular embodiment, the file contains a parameter called "ThetaInfluenceArray," which is an integer array representing how much the amplitude of brain waves in the theta range are to affect the level of output of the chemical, compound, and/or element, and with which compartment, as indicated by the index of the array. So the higher this value, the more the amplitude of brain waves in the theta range affects the percentages used to determine the composition. In a particular embodiment, the weighting scale is 0-100 and there is also an AlphaInfluenceArray. In a particular embodiment, a value in ThetaInfluenceArray[2105] of 50 and AlphaInfluenceArray

[2105] of 50 indicates that the level of output from compartment **2105** in the scent/flavor output device **1917** should be 50% determined by the amplitude of brain waves in the Theta range and 50% determined by the amplitude of brain waves in the Alpha range. This is just an example of how the algorithm used in creative circuit module **1908** can be made flexible through the use of parameter data. FIG. **26** provides examples of other parameters that may be used for flavor/scent outputs, as described herein.

Once creative circuit module **1908** has determined the percentages to use of the substances in each compartment of the scent/flavor output device **1917**, it sends this data to scent/flavor production module **1913**, which is configured to provide instructions to the scent/flavor output device **1917**. Based on these control instructions from the scent/flavor production module **1913**, scent/flavor output device **1917** combines the materials in the compartments it has available in a specific manner and proportions unique to that individual, and outputs a chemical, element, and/or compound (**2101** or **2102**, for example) that the user can either taste or smell or both.

In addition to audio, video, and taste/scent experiences, the system **1900** supports generation of tactile experiences. FIG. **22** provides an overview of the interaction between the human subject **2165**, bio/neurometric data generated by the subject, and the components needed to generate a tactile experience based on the combination of the B/N data and input parameters describing a user's preferred level and type of tactile experience.

As shown in FIG. **22**, the system **1900** may comprise a tactile production module **1914**, which is a software module capable of sending command and control data to a tactile output device **1918**, such as, e.g., tactile output device **2210** shown in FIG. **22**, via a wired or wireless interface. The illustrated tactile output device **2210** includes three pressure delivery strips **2212** that can deliver pressure to a user's back. In one implementation, these strips **2212** are individually controlled by commands sent to the tactile output device **2210** via a Bluetooth connection **2150**. In particular, tactile production module **1914** may be configured to generate a control sequence and send it to tactile output device **2210**. The control sequence may instruct tactile output device **2210** to start, stop, or change the speed or pattern of a given pressure delivery strip **2212** on the tactile output device **2210**. One example of a "smart" back massager with settings that may be controlled by the tactile production module **1914** is described at https://www.jialekangmassager.com/new-multi-functions-massage-cushion-chair-massage-pad-luxury-back-massager-with-jade-heads-and-bluetooth_p2.html. The protocol used by tactile output device **2210** may be specific to each tactile output device manufacturer, so the tactile production module **1914** may be manufacturer-specific as well. For instance, a manufacturer of a "smart" back massager may require that commands be sent in a specific j son data format over a Bluetooth connection, with a protocol defining what j son element names are used for each operation. For instance, in a particular embodiment, the array {["Start", 1, 5]} is a command sent from the tactile output device **2210** to the tactile production module **1914** telling it to start sending pulses from the first pressure strip at a speed of 5 pulses/second. A given manufacturer's tactile output device **2210** could also have the capability to delivery heat from the pressure delivery strips **2212**, or to activate pulses of delivery in a pattern around the strips **2212**. All of these capabilities could be controlled by a network protocol understood by the tactile production module **1914**.

Computing device **1907** of FIG. **22** contains components identical to those shown in FIG. **19**, including memory **1909**, processor **1910**, and creative circuit module **1908**. Tactile production module **1914** is a software component that could be running on the same system **1900** as creative circuit module **1908**, and is also shown in FIG. **19** as an option. In some embodiments, the tactile production module **1914** could be a separate object rather than integrated into the computing device **1907**, in which case tactile production module **1914** would have its own computing capability (e.g., memory, processor, and/or storage). The creative circuit module **1908** communicates with tactile production module **1914**. One possible dataflow is as follows: Human subject **2165** wears the neuro headset **2160** (such as a MUSE headset) as well as a heart rate/HRV monitor **2155** (such as a Fitbit or Apple watch). Data from these devices is transmitted over Bluetooth or other network protocol **2150** through the bio/neurometric data collector **1901** to the bio/neurometric data receiver **1902** (as shown in FIG. **19**) and then to creative circuit module **1908** (a software component within computing device **1907**. The subject **2165** is wearing tactile output device **2210** against his back, or other body part). Creative circuit module **1908** will use this data in conjunction with a parameter file stored in memory **1909** to determine a set of output values to send to tactile production module **1914**.

One way of having bio/neurometric data influence the tactile output is to have the strength of vibration of different strips **2212** (or pads) be controlled by different parameters, such that pad 1 could be controlled by changes in heart rate intensity, pad 2 could be controlled by changes in heart rate variability, and pad 3 could be controlled by changes in amplitude of brain waves in the Beta range, for example. The parameter file can be used to determine how the bio/neurometric data will affect the output values. For instance, in a particular embodiment, the file contains a parameter called "HRTactileMultiplier," which is an integer that is used to determine a speed of pad 1. For example, Heart Rate×HRTactileMultiplier1 is the number of vibrations per minute for pad 1. FIG. **25** lists more examples of parameters that may be used for tactile outputs, as described below.

Different tactile output devices will have different capabilities, and might be entirely different in function. For instance, in some embodiments, a "Smart" glove delivers pressure or temperature changes to each finger. This is accommodated by the architecture. So the parameter file could contain a variable tactile output device-type, which indicates the type of tactile output device. For tactile output device-type="BackMassager1," the HRTactileMultiplier1 described above may refer to pressure delivery strip number 1 on back massage tactile output device **2210**, while for tactile output device-type="Glove1," the HRTactileMultiplier1 may refer to finger #1. In both cases the creative circuit module **1908** would send a message to tactile production module **1914** (with the logic to send this command implemented in a processing plug-in as previously described), and tactile production module **1914** would send the appropriate control command to the tactile output device **2210** for that particular device.

Regarding the protocol used to communicate between tactile production module **1914** to tactile output device **1918** or **2210**, an example of an appropriate protocol to implement for message passing is Open Sound Control, as described previously and also proposed for use in communicating between the visual output production module (or graphics/animator engine **1911**) and the visual output device **1915**.

Although the name open sound control implies a reference to sound in particular, this protocol is designed to allow for a user-defined message set, which can have nothing to do with sound, as in this case. So for instance, a message can be passed from the creative circuit module **1908** to tactile production module **1914** such as ["PulseSpeed", 1, 5], which would indicate to set the pulse speed on pressure delivery point 1 to "5". Similarly, a command such as ["Pressure-AndHeat", 1, 0.5, 80.0] would indicate to set the delivery pressure to 0.5 strength and temperature to 80.0 degrees Fahrenheit for pressure delivery point 1. Tactile production module **1914** will interpret this appropriately based on the type of tactile output device **1918** it is controlling. The communication between tactile production module **1914** and the tactile output device **1918** will be manufacturer-specific, and may or may not use a standard such as Open Sound Control.

All scenarios discussed thus far can be used with either one human subject or multiple human subjects providing bio/neurometric data and/or receiving the specified sensory experience. To illustrate this, FIG. **23** provides an example of use of the system **1900** in a group setting, combining both visual and tactile components. FIG. **23** depicts a theater **2300** with a projection screen **2301** and a visual output device **1915**, or in this case, a smart projector **2350** that projects images on the screen **2301**. Human subjects **2306***a*, **2306***b*, and **2306***c* sit in seats **2305***a*, **2305***b*, and **2305***c* which are outfitted with tactile output devices **2210** in the form of back massagers **2315***a*, **2315***b*, and **2315***c*, respectively. Bio/neurometric data obtained from neuro headsets **2310***a*, **2310***b*, and **2310***c* worn by the users **2306***a*, **2306***b*, and **2306***c* respectively (and possibly also heart rate monitors (not shown)) is transmitted over a WIFI or other wireless network connection **2150** to computing device **1907**, which houses the components shown within it in FIG. **19**. Creative circuit module **1908** will use the aggregated data from all users in conjunction with a parameter file stored within memory **1909** to determine digitized visual output data to project on screen **2301**. Data from all users could be averaged, or min/max, median approaches could be used by the algorithm in creative circuit module **1908**, as influenced by the parameter file with Booleans such as useMin, UseMax or UseMedian. The computing device **1907** would also contain the software component for communication with the back massagers **2315***a*, **2315***b*, and **2315***c* in the seats **2305***a*, **2305***b*, and **2305***c* and thusly, aggregated data could also control both the visual and the tactile experience of the seated human subjects **2306***a*, **2306***b*, and **2306***c*, respectively.

Usage examples of the disclosed invention covering different senses are as follows:

Sound: A user listens to a piece of music generated by a MIDI stream from either a MIDI file or a live performance (with the performer or performers using MIDI-capable instruments. MIDI monitoring software is used to capture the MIDI stream, including the MIDI control messages. The piece is presented to the user in sections. As she is listening, the user notes her level of enjoyment of each section. The captured MIDI stream plus the user's feedback is used to create a vocabulary and set parameters that will be used to create new content (e.g., as shown in FIG. **28**). In addition to pitch and velocity, attributes such as vibrato and reverb can be part of the vocabulary controlled by use of the MIDI control message. The user is outfitted with biometric data capturing equipment, and the system generates new content from this vocabulary and parameters.

Sight: Using a computer-based object and shape recognition system, a painting or video is analyzed, and the "vocabulary" of the painting/video is extracted (e.g., as shown in FIG. **28**). Size, shape, angle values, hue, saturation, and chroma can all be part of the vocabulary, as well as speed and direction in the case of animation. This vocabulary is employed along with parameters set and varied during playback according to user and operator choice. The user is outfitted with biometric data capturing equipment, and a computer graphics/animation system generates new visual content from this vocabulary and parameters.

Smell and/or Taste: The scent coming from different areas of a field of flowers is analyzed to determine the chemical makeup of the volatile organic compounds in the air that create the scents. The user's subjective report of the scents in the air is also recorded and his preference for which scents he enjoys most. The user is outfitted with biometric data capturing equipment, and the information from the analysis plus the user's feedback is used to create a vocabulary and set parameters that will be used to create aromas, generated by a computer controlled aromatherapy device (e.g., as shown in FIG. **28**). This device is loaded with chemical compounds determined by the vocabulary. Alternatively, a drink the user enjoys could be analyzed to determine the chemical compounds that create the taste. The user is outfitted with biometric data capturing equipment, and the information from analysis plus the user's feedback is used to create a vocabulary and set parameters that will be used to create a custom drink generated by a computer-controlled cocktail-making device loaded with liquids based on the vocabulary.

Touch: Just as a vocabulary can be created for use in audio, visual, taste, and scent experiences, a tactile vocabulary can be defined (e.g., as shown in FIG. **28**). In the case of a massage device, the tactile vocabulary may be expressed as temperature, pressure level, rate of pressure delivery (pressure pulses/second), location of pressure delivery or style (sequential across pressure delivery points in a predefined sequence or random). To define a custom vocabulary that matches his preferences, a user could operate a back massage device with an ability to deliver varying temperature, pressure, and rate, and the settings the user enjoys can be captured. These settings would be entered into a parameter file. The file could map the types of massage delivery the user enjoys to brain and/or body states such that, for example, when a target power of theta at a given electrode site or a given heart rate or HRV level is hit, the system responds with a given massage and/or temperature (or heat) mode.

FIG. **24** illustrates a table **2400** with examples of how values in the TCCS parameter file can determine which targeting plug-in, processing plug-in, audio engine, and/or video or visual engine to use during operation of the system **1900**, in accordance with embodiments. The table **2400** may be similar to the table **1500** shown in FIG. **15** to illustrate the configurable nature of the plug-in architecture described herein. In particular, the table **2400** lists the name of exemplary TCCS parameters, a description of each, and an explanation of how each parameter is used in tactile outputs and flavor/scent outputs. In table **2400**, the given TCCS parameter may be used in the tactile output to influence data values passed to the tactile output production module, for example, via OSC or other data streaming protocols, and may be used in the scent/flavor output to influence data values passed to the scent/flavor production module, for example, via OSC or other streaming data protocols.

To further illustrate what an exemplary plug-in may look like, FIG. **25** depicts a table **2500** that describes an exemplary set of parameters (e.g., TCCS parameters) and shows how these parameters could be used within an exemplary processing plug-in for generating tactile outputs. Similarly, FIG. **26** illustrates a table **2600** describes an exemplary set of parameters (e.g., TCCS parameters) and shows how these parameters could be used within an exemplary processing plug-in for generating flavor/scent outputs. The tables **2500** and **2600** may be similar to, and used in a similar manner as, the table **1600** shown in FIGS. **16**A, **16**B, and **16**C, except for producing tactile or flavor/scent outputs.

FIG. **27** depicts a table **2700** summarizing several possible examples of how a given creative circuit system (such as, e.g., the system **1900** shown in FIG. **19**) can be setup and used, in accordance with embodiments. It should be appreciated that the table **2700** does not provide an exhaustive list of uses and that other uses are also contemplated. Also, while the examples provided in table **2700** use EEG data, all examples could be setup with other biometric data input such as, e.g., heart rate, blood pressure or galvanic skin response, using techniques described herein.

FIG. **28** depicts a table **2800** that lists various sensory experience categories that may be used by the system **1900** of FIG. **19** and exemplary vocabulary elements and methods of vocabulary formation for each category, as well as examples of a delivery mechanism for each category. As will be appreciated, the table **2800** is a non-exhaustive list and other vocabulary elements, formation methods, and/or delivery mechanisms may be used.

In the context of this document, a "computer-readable medium" may be any means that can store, communicate, propagate, or transport data objects for use by or in connection with the system **100**, or any other systems described here. The computer readable medium may be for example, an electronic, magnetic, optical, electromagnetic, infrared, or semiconductor system, apparatus, device, propagation medium, or any other device with similar functionality. More specific examples (a non-exhaustive list) of the computer-readable medium would include the following: an electrical connection (electronic) having one or more wires, a random access memory (RAM) (electronic), a read-only memory (ROM) (electronic), an erasable programmable read-only memory (EPROM, EEPROM, or Flash memory) (electronic), an optical fiber (optical), and a portable compact disc read-only memory (CDROM) (optical). Note that the computer-readable medium could even be paper or another suitable medium upon which the program is printed, as the program can be electronically captured, via, for instance, optical scanning of the paper or other medium, then compiled, interpreted or otherwise processed in a suitable manner if necessary, and stored in a computer memory. Portions of the systems, modules and/or processes described herein can be embodied in any type of computer-readable medium for use by or in connection with an instruction execution system or apparatus, such as a computer.

Any process descriptions or blocks in figures should be understood as representing modules, segments, or portions of code which include one or more executable instructions for implementing specific logical functions or steps in the process, and alternate implementations are included within the scope of the embodiments of the invention in which functions may be executed out of order from that shown or discussed, including substantially concurrently or in reverse order, depending on the functionality involved, as would be understood by those having ordinary skill in the art.

It will be understood by those skilled in the art that various changes may be made and equivalents may be substituted without departing from the scope of the novel and non-obvious techniques disclosed in this application. Therefore, it is intended that the novel teachings of the invention not be limited to the particular embodiments disclosed, but that they will include all embodiments falling within the scope of the appended claims.

What is claimed is:

1. A method of creating a coherent output based on biometric and/or neurometric data using a computing device comprising one or more processors and memory, the method comprising:

receiving a first incoming signal from a first bio-generated data sensing device worn by a user;

receiving, from a sensory input system, a first input signal representing sensory content experienced by the user in association with generation of the first incoming signal;

using the one or more processors, populating a common vocabulary with one or more values determined based on the first input signal, the common vocabulary being stored in the memory;

determining, using the one or more processors, a first set of output values based on the first incoming signal, the common vocabulary, and a parameter file stored in the memory, the common vocabulary comprising a list of possible output values, and the parameter file comprising a set of instructions for applying the common vocabulary to the first incoming signal to derive the first set of output values;

generating, using the one or more processors, a first output array comprising the first set of output values; and

providing the first output array to an output delivery system configured to render the first output array as a first sensory output.

2. The method of claim **1**, wherein the first sensory output is a tactile output comprising vibrations determined based on the first output array, and the output delivery system comprises one or more vibration output devices for generating the vibrations.

3. The method of claim **1**, wherein the first sensory output is an aroma output having a scent determined based on the first output array, and the output delivery system comprises one or more scent output devices for generating the scent.

4. The method of claim **1**, wherein the first sensory output is a consumable item having a flavor determined based on the first output array, and the output delivery system includes one or more flavor output devices for generating the flavor.

5. The method of claim **1**, wherein the sensory input system comprises a tactile input source, and the sensory content is vibratory content applied to the user, the first input signal including first data identifying a pressure level of the vibratory content and second data identifying a temperature level of the vibratory content.

6. The method of claim **1**, wherein the sensory input system comprises a material analysis device, and the sensory content is a source material consumed by the user, the first input signal comprising data identifying one or more components of the source material.

7. The method of claim **1**, wherein the first bio-generated data sensing device is a monitor configured to collect heart rate intensity or heart date variability data of the user.

8. The method of claim **1**, wherein the first bio-generated data sensing device is a headset configured to collect electroencephalography ("EEG") signals of the user.

9. The method of claim 1, further comprising:

receiving a second incoming signal from a second bio-generated data sensing device worn by the user;

determining, using the one or more processors, a second set of output values based on the second incoming signal, the common vocabulary, and the parameter file, wherein the parameter file further comprises a set of instructions for applying the common vocabulary to the second incoming signal;

generating, using the one or more processors, a second output array comprising the second set of output values; and

providing the second output array to the output delivery system, the output delivery system further configured to render the second output array as a second sensory output.

10. The method of claim 1, further comprising:

receiving a second input signal, from an audio/visual input system, representing audio content produced by the user during receipt of the first incoming signal;

populating the common vocabulary based further on the second input signal using a spectral analyzer and the one or more processors;

determining, using the one or more processors, a third set of output values based on the first incoming signal, the common vocabulary, and the parameter file;

generating, using the one or more processors, a third output array comprising the third set of output values; and

providing the third output array to the output delivery system, the output delivery system further configured to render the third output array as an audio output.

11. The method of claim 10, wherein the third set of output values comprises Musical Instrument Digital Interface ("MIDI") data.

12. The method of claim 1, wherein the common vocabulary is populated with values determined based on different types of sensory experiences, the first input signal being associated with a first sensory experience, and the output array being associated with a second sensory experience that is different from the first sensory experience.

13. A system, comprising:

a bio-generated data sensing device worn by a user and configured to detect a first electrical signal representing biometric and/or neurometric data of the user;

a sensory input system configured to provide a first input signal representing sensory content experienced by the user in association with detection of the first electrical signal;

a memory configured to store a parameter file and a common vocabulary;

one or more processors configured to:

receive the first input signal from the sensory input system;

populate the common vocabulary with one or more values determined based on the first input signal;

determine a first set of output values based on the first electrical signal, the common vocabulary, and the parameter file, and

generate a first output array comprising the first set of output values; and

an output delivery system configured to render the first output array as a first sensory output,

wherein the common vocabulary comprises a list of possible output values, and the parameter file comprises a set of instructions for applying the common vocabulary to the first electrical signal to derive the first set of output values.

14. The system of claim 13, wherein the bio-generated data sensing device is a headset configured to collect electroencephalography ("EEG") signals of the user.

15. The system of claim 13, wherein the bio-generated data sensing device is a monitor configured to collect heart rate intensity or heart date variability data of the user.

16. The system of claim 13, wherein the first sensory output is a tactile output comprising vibrations determined based on the first output array, and the output delivery system comprises one or more vibration output devices configured to generate the vibrations.

17. The system of claim 13, wherein the first sensory output is an aroma output having a scent determined based on the first output array, and the output delivery system comprises one or more scent output devices for generating the scent.

18. The system of claim 13, wherein the first sensory output is a consumable item having a flavor determined based on the first output array, and the output delivery system includes one or more flavor output devices for generating the flavor.

19. The system of claim 13, wherein the sensory input system comprises a tactile input source, and the sensory content is vibratory content applied to the user, the first input signal including first data identifying a pressure level of the vibratory content and second data identifying a temperature level of the vibratory content.

20. The system of claim 13, wherein the sensory input system comprises a material analysis device, and the sensory content is a source material consumed by the user, the first input signal comprising data identifying one or more components of the source material.

21. The system of claim 13, further comprising:

a second bio-generated data sensing device worn by the user and configured to detect a second electrical signal representing second biometric and/or neurometric data of the user,

wherein the one or more processors are further configured to:

determine a second set of output values based on the second electrical signal, the common vocabulary, and the parameter file, wherein the parameter file further comprises a set of instructions for applying the common vocabulary to the second electrical signal; and

generate a second output array comprising the second set of output values, and

wherein the output delivery system is further configured to render the second output array as a second sensory output.

22. The system of claim 13, further comprising:

an audio/visual input system configured to provide a second input signal representing audio content produced by the user during detection of the first electrical signal; and

a spectral analyzer configured to identify one or more aspects of the second input signal,

wherein the one or more processors are further configured to:

populate the common vocabulary based further on the identified aspects of the second input signal;

determine a third set of output values based on the first electrical signal, the common vocabulary, and the parameter file;

generate a third output array comprising the third set of output values; and

provide the third output array to the output delivery system,

wherein the output delivery system is further configured to render the third output array as an audio output.

23. The system of claim **22**, wherein the third set of output values comprises Musical Instrument Digital Interface ("MIDI") data.

24. The system of claim **13**, wherein the common vocabulary is populated with values determined based on different types of sensory experiences, the first input signal being associated with a first sensory experience, and the output array being associated with a second sensory experience that is different from the first sensory experience.

25. A system, comprising:

a first bio-generated data sensing device worn by a first user and configured to detect a first electrical signal representing biometric and/or neurometric data of the first user;

a second bio-generated data sensing device worn by a second user and configured to detect a second electrical signal representing biometric and/or neurometric data of the second user;

a memory configured to store a parameter file and a common vocabulary;

one or more processors configured to:

determine a set of output values based on the first electrical signal, the second electrical signal, the common vocabulary, and the parameter file, and

generate an output array comprising the set of output values; and

an output delivery system configured to render the first output array as a first sensory output for the first user and a second sensory output for the second user,

wherein the common vocabulary comprises a list of possible output values, and the parameter file comprises a set of instructions for applying the common vocabulary to each of the first electrical signal and the second electrical signal to derive the set of output values.

26. The system of claim **25**, further comprising a sensory input system configured to provide: a first input signal representing sensory content experienced by the first user in association with detection of the first electrical signal, and a second input signal representing sensory content experienced by the second user in association with detection of the second electrical signal, wherein the one or more processors are further configured to:

receive the first and second input signals from the sensory input system, and

populate the common vocabulary with one or more values determined based on the first input signal and the second input signal.

27. The system of claim **25**, wherein each of the first bio-generated data sensing device and the second bio-generated data sensing device is a headset configured to collect electroencephalography ("EEG") signals or the is a monitor configured to collect heart rate intensity or heart date variability data.

* * * * *